CFTRI-MYSORE
2433
Bibliography of

Tms

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

BIBLIOGRAPHY

OF

INDUSTRIAL DRYING

9372a
1.1

VOLUME I

DECEMBER 1951

Price 27s 6d (3 Volumes)

The Bibliography of Industrial Drying is divided into five sections and presented for convenience in three volumes. A contents list for the relevant sections is included at the beginning of each volume and a list of sources quoted in the text, is given at the end of Volume III.

F8,3:6;4“a
N51·1

VOLUME I.	Section	1.	Principles of Drying
	"	2.	Drying Processes and Equipment
VOLUME II.	Section	3.	Agriculture
	"	4.	Food
VOLUME III.	Section	5.	Industrial Materials
			List of Sources Quoted in the Text

CFTRI-MYSORE
2433
Bibliography of

(Reprinted with minor amendments, November, 1952)

INDUSTRIAL DRYING

In 1948, Sir Frank Engledow, Chairman of the Food Investigation Board, Department of Scientific and Industrial Research, drew attention to the importance of increased efficiency in industrial drying processes; in particular he emphasised the value of (a) pooling the knowledge of methods used in different industries, (b) studying the efficiency of different drying processes, and (c) formulating and providing for the fundamental research problems of industrial drying. The present bibliography is intended to make a contribution towards meeting the first of these requirements.

Industrial drying has acquired much prominence in recent years, largely on account of the necessity for general economy in the use of fuel and the desirability of improving the operating efficiency of drying processes which, in contrast with former practice, can no longer afford to be prodigal in energy consumption. In addition, new and improved processes and equipment have enabled great advances to be made in regard to the drying and preservation of materials sensitive to heat and oxidation and to methods for extremely rapid drying.

The interchange of technical information, however, between one industry and another and among those concerned generally with drying has not always kept pace with technical development. The information is dispersed and often in unrelated form, and although symposia on particular aspects of drying have been held from time to time in conformity with the greatly increased interest in the mechanism of drying since about 1920, it is largely the stimulus of necessity which is now giving added stress to the importance of making the maximum use of available knowledge for process improvement and economy. Recent efforts to this end are seen in the series of 15 papers on the use of fuel in drying, presented at the Ministry of Fuel and Power Conference in 1946 and embodied in the Ministry publication "Fuel and the Future" (H.M.S.O.). More recently the same Ministry has embarked on a practical survey of the efficiency of drying operations in various industries. Data on fuel, power and steam consumption for the drying of certain materials such as grass and grain, vegetables, milk and flax have been recorded by the Ministries concerned. The survey of the Ministry of Fuel and Power however, is intended to cover a much greater number of industries. Lastly in 1950-1951 the Institute of Fuel carried out a Study of Drying in a series of conferences, at which about 50 papers were presented. This study also made its approach from the point of view of the materials and industries themselves. Moreover, it placed considerable emphasis on outstanding problems in the various fields surveyed.

The literature of drying is dispersed among many hundreds of periodicals and other publications. Some eight hundred sources covering over four thousand five hundred entries are quoted in the present volumes and listed at the end. A general, bibliography was compiled in 1924 by S. C. Chigison and presented by E. A. Alliott in the Transactions of the Institute of Chemical Engineers, Vol. 2, 1924, pp.93-110. This compilation consisted of some 500 annotated references covering the period 1900-1924, classified under the names of the periodicals in which they appeared and indexed under subject headings. Since then substantial bibliographies have been compiled to cover special subjects such as the dehydration of foods, by Heinz & Co., the drying of peat by the Experimental Station, Bord Na Mona, Dublin, the drying of rubber by the British Rubber Manufacturers Res. Assn. the drying of fodder crops by Miss M. Yeo and smaller collections included in the Science Library Bibliographical Series. In 1946, Industrial and Engineering Chemistry

2433

began its series of annual reviews of the current literature on Unit Chemical Engineering Operations. One of these is the subject of Drying by S. J. Friedman, in which up to 200 literature contributions are reviewed annually. Reference should also be made to the Du Pont card file, which includes some thousands of references on drying. It is regretted that the copy of the relevant part of this file was not received in time to be used in preparation of the present publication.

An attempt has been made here to classify under appropriate headings. The headings used are those which seemed appropriate to the main subject matter of the papers concerned, and the references are placed in alphabetical order of authors' names under each heading. The classification was adopted in order to break down the larger sections as far as practicable, although in some cases the breakdown may seem artificial. It is doubtful whether any classification free from ambiguity could be attained except by inclusion of extensive cross reference or duplication, which, in the present bibliography, has been reduced to a very small proportion. The period covered is 1924 to 1950, although a number of references outside this period have been included. The material has been gathered by direct reference to published papers, from compilations of abstracts already published by, or in possession of, the Department, such as Fuel Abstracts and Food Science Abstracts, and from certain other abstracting services. In addition, Dr. T. K. Sherwood, Dean of the Massachusetts Institute of Technology, kindly made available his private collection of over 1,000 references on drying. The special bibliographies already referred to have been obtained, although these are not entered in detail herein. We are indebted to the following organizations for permission to use their published abstracts:-

American Chemical Society, Chemical Abstracts
Battelle Memorial Institute, U.S.A.
Bureau of Abstracts, U.K.
Commonwealth Agricultural Bureaux
British Ceramic Research Association
British Cotton Industry Research Association
British Food Manufacturing Industries Research Association
British Leather Manufacturers' Research Association
The Textile Institute
Wool Industries Research Association.

A definition of drying is not easy to formulate. Drying is normally regarded as the removal of moisture by evaporation, generally with the aid of heating appliances; industrial processes such as evaporation and mechanical dewatering would be excluded. Some instances of the latter, however, are included here on account of novelty or for special reasons. Insofar as mechanical dewatering is related to the drying operation, it is not always realised that the greatest single economy in drying may lie in efficient mechanical dewatering beforehand.

The literature on the drying of gases and on air conditioning is very extensive. A small number only of references on this subject are included, and similarly for heat transfer. The serial numbers to the entries are for convenience of assembly only.

F95.3 OF4a
D.J1.1

W. H. BICKLE,

December, 1951.

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE
29 MAY 1953
LIBRARY
* MYSORE. *

VOLUME I - CONTENTS

SECTION I

GENERAL PRINCIPLES

FUNDAMENTALS

	Pages	Item Nos.
General	1 - 23	1 - 140
Evaporation	23 - 36	141 - 210
Diffusion	36 - 45	211 - 267
Permeability	45 - 50	268 - 295
Thermal Conductivity	51 - 52	296 - 302
Heat Transfer	52 - 59	303 - 349
Humidity, Hygrometry	59 - 68	350 - 415
(Control Solutions)	68 - 69	416 - 420

INSTRUMENTS (Hygrometric) instrumentation

	Pages	Item Nos.
General	69 - 72	421 - 441
Dew Point Instruments	73 - 74	442 - 450
Electrolytic Instruments	74 - 77	451 - 463
Electric and Thermo-electric Instruments	77 - 80	464 - 476
Wet and Dry Bulb Instruments	80 - 81	477 - 489
INSTRUMENTS (Not Hygrometric)	82 - 83	490 - 501

MOISTURE DETERMINATION

	Pages	Item Nos.
General	84 - 87	502 - 520
Electrical Methods	87 - 90	521 - 536
Fischer Method	90 - 91	537 - 544
Gas Evolution Method	91 - 92	545 - 550
Hygrometric Methods	92 - 93	551 - 554

SOLD BY
PROGRESS
BOOK-STALL,
MYSORE.

	Pages	Item Nos.
SORPTION		
General	93 - 98	555 - 586
Liquid Sorbents	98 - 100	587 - 600
Solid Sorbents	101 - 107	601 - 638
AIR CONDITIONING AND GAS DRYING	107 - 125	639 - 760
ADDENDUM	126 - 128	761 - 783

SECTION 2

drying equipments

DRYING PROCESSES AND EQUIPMENT

	Pages	Item Nos.
DRYING, GENERAL	137 - 153	1 - 116
EQUIPMENT GENERAL	154 - 167	117 - 230
CONTROL	168 - 170	231 - 254
EFFICIENCY	171 - 174	Sect. 5, 1501-2 255 - 279
CORROSION	175	280 - 283
CYCLONES	175 - 177	284 - 293
FILM AND DRUM DRYING	177 - 179	294 - 312
ELECTRO-ENDOSMOSIS	179 - 181	313 - 323
FREEZE CONCENTRATION	182 - 183	324 - 333
FREEZE DRYING (Drying by Sublimation)	184 - 193	334 - 394
HEAT PUMP. Appln. of.	193 - 195	395 - 406

HIGH (RADIO) FREQUENCY (DIELECTRIC) HEATING

	Pages	Item Nos.
General Principles	196-202	407 - 441
Applications	202-205	442 - 457

INFRA-RED (RADIANT) HEATING

General Principles	206 - 212	458 - 485
General Applications	212 - 226	486 - 548
Equipment, General	226 - 227	549 - 555
" Electric	227 - 229	556 - 574
" Gas	229 - 236	575 - 608
MILL DRYING	237 - 238	609 - 614
PACKAGING	238 - 239	615 - 623
PNEUMATIC DRYING	239 - 244	624 - 658
ROTARY	245 - 254	659 - 717

SPRAY DRYING

Process General	254 - 261	718 - 767
Equipment	262 - 264	768 - 792
Atomisation	264 - 270	793 - 828
Evaporation	270 - 271	829 - 833
SOLAR HEAT. Use of	271 - 273	834 - 841
TRAY DRYING	273 - 274	842 - 851
TUNNEL DRYING	275 - 276	852 - 862

TURBO DRYERS

	Pages	Item Nos.
General	277 - 278	863 - 873
Equipment	278 - 279	874 - 880
ULTRA-SONICS. Use of.	280	881 - 882

VACUUM DRYING

	Pages	Item Nos.
General	281 - 285	883 - 925
Fundamentals	285 - 286	926 - 936
ADDENDUM	287 - 289	937 - 949

SECTION I

FUNDAMENTAL PRINCIPLES

General Principles

1. ---- Discussions Forad.Soc.No.3,1948 300 pp.
INTRACTION OF WATER AND POROUS MATERIALS. A series of 32 papers. 12 papers on fundamental aspects 7 papers on botanical aspects. 7 papers on Zoological aspects 5 papers on Textiles etc. aspects 1 paper on Oleophobic aspects. Discussion on each section.

2. Various authors Ind.Eng.Chem.30 1119-1138,1938 Symposium

Drying Commercial Solids.	Ernst Ardern Schmied. Tiller.
Practical Vacuum Drying.	Ernst Ridgway Tiller.
Evaporation of Water into Quiet Air	Sharpley Boelter
Rate of Evaporation from a Free Water Surface by a Perpendicular Air Stream	Molstad Farevaag Farrell

3. Adam, N. K. Discuss Forad Soc.No.3 1948 pp.5-10
PRINCIPLES OF PENETRATION OF LIQUIDS INTO SOLIDS.

4. Aganov, A. I. Zh.Tekh.Fiz.6(9)1601-7 1936
The Determination of Effective Radius of Pores in Porous Materials. The method depends on the creation of a vacuum at a moment when the capillary passes a rather steep section of its characteristic curve. D.S.I.R./3137/C.T.

5. Alison, A. Indus.Chemist(Lond.),Vol.6,No.69, Oct.1930,pp.402-403,1 fig.
THE REMOVAL OF WATER DURING CONCENTRATION. Nomographic method to ascertain quantity of water which must be expelled in order to derive from weak solution another of requisite strength.

6. Ambler, C. M. Chem.Eng.Progress 44(5)1949 Trans.Amer. Inst.Chem.Engrs,405-410 1948
AN ATTEMPT TO DEVELOP A THEORY OF CRYSTAL-DRYING.

7. Bangham, D. H. Soc.Chem.Industr.,Symposium on Shrinkage and Cracking of Cementive Materials,p.29, 1947
THE SWELLING AND SHRINKAGE OF POROUS MATERIALS AND THE ROLE OF SURFACE FORCES IN DETERMINING TECHNICAL STRENGTH. A study is made of the swelling which porous materials - in the experiments wood

TECHNOLOGICAL RESEARCH

charcoal — undergo whilst adsorbing gases and vapours. It is shown that expansion is directly proportional to the lowering of the surface tension of the particles which accompanies adsorption. The surface forces become effective in proportion to the area over which they act. If, for example, an aggregate is submitted to compressive stresses which are then removed, the opportunity thus given for the surface forces to assert themselves over larger areas of contact may prevent a complete return to the original condition. The surface tension of the particles may be increased by an adsorbed film if the film itself has surface tension. (5 figs.)

8. Banks, W. H. and Barkas, W. W. — Nature, 158, 341, 1946

COLLAPSE OF CAPILLARIES IN THE DRYING OF POROUS GELS. It is shown that in materials softer than rubber, microscopically visible voids can collapse at humidities very close to saturation, causing abnormal external shrinkage at high moisture contents. This applies to natural gels, such as wood. Expresses the minimum initial radius of capillaries that can exist in a material without collapsing during complete drying. This minimum radius is expressed as a function of rigidity of the material, surface tension of the liquid evaporating, and the contact angle between liquid and solid. Below the minimum humidity no capillary moisture is present, since the capillaries smaller than the minimum have collapsed and larger ones will be dry. Example 98% R.H. for rubber.

9. Barberot — Rev.materiaux construction trav.publx. 101-413(1933)

THEORY OF ARTIFICIAL DRYING.

9a. Becker, F. C. et al. — Naturvidenskabelige Samfund. Denmark 1925. 34 pp.

DRYING PROCESSES.

9b. Boon, W. L. — Inst. Fuel "Drying Study" Discussion 25 April 1951

THE IMPORTANCE OF SUCH A STUDY IN SUPPLYING A NEED FOR A WIDER GENERAL KNOWLEDGE OF DRYING AND ITS EFFICIENT CONDUCT.

10. Broughton, D. B. — Ind. Eng. Chem., 37, 1, 184-5 1945

THE DRYING OF SOLIDS. The average moisture concentration at the critical point in the drying of a solid is expressed in terms of the drying conditions and the nature of the material. This relation is developed on the assumption that the surface moisture concentration at the critical point is a function only of the nature of the material. The relation proposed here is shown to be supported by several sets of data on kaolin and clays.

11. Brown and Associates Wiley & Sons, New York, Chapman & Hall, London, 1950 592 pp.
UNIT OPERATIONS. Chapter 37. Simultaneous heat and mass transfer. Psychrometry Drying. Spray drying and film drying equipment and Dryer calculations.

12. Brown, R. C. Proc. Phys. Soc., 1947, 59, 429-448
SURFACE TENSION AND CAPILLARITY: FUNDAMENTAL CONCEPTS. On the basis of the usual idea of cohesion between molecules it is shown that it is not necessary to deny the reality of surface tension, and an attempt is made to account for it in a physical manner. It is also shown that it is possible to gain a less abstract conception of the distinction between free and total surface energy than that provided by a purely thermodynamical discussion. The customary assumption that in a system containing a solid/liquid interface the surface energy of the solid plays an identical role with that of the liquid is criticised, and the conception of surface energy as the work done during the rupture of a column of material is examined. Capillary elevation is regarded as a consequence of negative surface tension in the liquid at the solid/liquid interface, and the usual expression for the capillary rise is derived from this idea.

13. Carne, J. B. Industr. Gas, Sept. 1947, 26, 15-17, 26-29
ROLE OF CONVECTION IN MEDIUM TEMPERATURE PROCESSING: WITH SPECIAL REFERENCE TO ITS INFLUENCE ON THE DESIGN OF "INFRA-RED" OVENS. PART III. New determinations of the coefficients of natural convection of spheres and vertical plates and influence of convective loss on the design and operation of infra-red equipment.

14. Carrier, W. H. J. Amer. Soc. Heat & Vent. Engrs. 24 227-248 1917-1918
THE TEMPERATURE OF EVAPORATION. Its application to air conditioning and to the drying and conditioning of materials. The application of psychrometric principles.

15. Cassie, A. B. D. Discuss Forad. Soc. No. 3 pp. 11-15 1948
CONTACT ANGLES.

16. Ceaglske, N. H. and Hougen, O. A. Indus. & Eng. Chem. v 29 n 7 July 1937 p. 805-13
DRYING GRANULAR SOLIDS. Methods described for calculating moisture distribution and average moisture content of granular solid for any thickness and for calculating drying rate curves during first and second falling periods, provided value at constant rate period is known. Before Am. Inst. Chem. Engrs. 15 references. See also Trans. Am. Inst. Chem. Eng. 33 1937.

17. Ceaglske, N. H. Trans. Amer. Inst. Chem. Engrs. 36 211-226 1940
Kiesling, F. C.
CAPILLARY FLOW IN POROUS SOLIDS. Follows paper by Ceaglske and Hougen, this journal 33 283 1937, for equilibrium conditions. The present paper provides data for actual flow due to capillarity, i.e. flow in absence of external pressure. It is concluded from the results of experiments with various sands that the force inducing capillary flow is produced by surface tension at the air-water interfaces 16 References.

18. Clegg, R. R. Paper Maker July Oct., Nov. 1944, 108, 5-8, 25-40 and 41-44 TS; Sci. Abstr. A. 1945, 48, 126
DRYING AND DRYERS. The physical mechanisms of the removal of moisture in various forms are considered; the cases of surface moisture, hygroscopic or inherent moisture, water of crystallization, materials with fine-bore capillaries, and a liquid with a solid in solution or in suspension, are distinguished. Conduction diagrams, insulation, and heat exchange, and contact, hot air, tray, hanging, continuous, conveyor, rotary-drum, circulating-fan and cascade driers, are discussed.

19. Clegg, R. R. J. Inst. Heat. Vent. Eng. Nov. and Dec. 1945, 13, 184-123)
THEORY AND PRACTICE OF DRYING BY MEANS OF HOT AIR. The author deals in a concise and comprehensive manner with a very complex subject, of great importance to-day to a wide variety of industries, as will be realized by examining the classification of materials given. The various principles involved are referred to briefly and elucidated by graphs. Different types of dryer - from the simple drying chamber to the multi-conveyor and rotary types used in modern drying and dehydrating processes - are described and their action made clear by simple diagrams.

20. Clinedienst, W. O. Amer. Gas Jnl. 162(3) 12-20 Mar. 1945
FLOW EQUATIONS FOR GAS, CONSIDERING DEVIATIONS FROM IDEAL GAS LAWS.

21. Corcoran, W.H. Rondebush, B. and Sage, B.H. Chem. Eng. Progress, 1947, 43. T. 135-142
TURBULENT GAS STREAMS: TEMPERATURE GRADIENTS. Equipment is described which permits the measurement of the temperature and velocity distribution in an air stream with essentially two-dimensional flow characteristics. Preliminary results including data describing the temperature and velocity distribution, heat transfer from the wall, and shearing stress are presented for seven different sets of conditions. The data indicate that within the accuracy of measurement the eddy viscosity and eddy conductivity are equal as was

assumed by von Karman (1939) in his analogy between the transfer of momentum and the thermal transfer of energy. The overall heat-transfer rate predicted by the Karman analogy agrees with the experimental results in the case of a symmetrical temperature distribution. However, significant divergences from the heat-transfer rates predicted by the analogy were experienced in the case of non-symmetrical temperature distributions.

22. Couch & Herrstrom — Jnl.Inst.Heat. & Vent.Engrs.p.223.1945-6
LAMINAR FLOW. Layer extended for a distance of 0.001 cm. to 0.02 cm. from the contact surface. Beyond was a turbulent zone which incorporated a buffer zone and this extended to a depth of 2 cms.

23. Cowen, W. — J.Soc.Dyers & Colorists, 55(6) 290-301. June 1939
SOME PRINCIPLES OF DRYING. 1. Moisture Relations. 2. The Boundary Layer. 3. Psychrometry & a chart. 4. Regain or equivalent moisture content. 5. Drying Curves. 6. Constant Rate Period. 7. Falling Rate Period. Appendix I. The Boundary Layer Theorem. Mathematical Treatment. Appendix II. The Rate of drying when the operation is controlled by the movement of the liquid through the solid. Large Bibliography divided into above sections.

24. Cross, A. H. B., Young, R. F. — Trans.Br.Ceram.Soc.49(5) 191-201, May 1950
NOMOGRAMS FOR APPARENT DENSITY AND POROSITY. Charts and their use for graphical solutions.

25. Danze, J. — Hommage de la Faculté des Sciences Appliquées. Centenaire de l'Assn.des des Ingenieurs de l'Ecole de Liege 1947
RECHERCHES SUR LE SÉCHAGE INDUSTRIEL. Mathematical analysis of the drying of a porous body by consideration a simple capillary in relation to the air flow.

26. Davis, W. A., Vargas Eyre, J. — Proc.Roy.Soc.A.104.p.512-537, 1923
THE DISCONTINUITY OF THE HYDRATION PROCESS. Tables of results, curves and analysis of experimental data on the hydration of:-

- Flax
- Ramie
- Cotton Wool
- Gelatin
- Anhydrite
- Copper Sulphate

The discontinuity of the absorption process is demonstrated.

27. Dickinson, D. F. — Iowa State Coll.J.Sci.17.51-53.1942
MUSLIN PILE DRYING. A method of studying drying mechanism that involves heat and mass transfer equations has been used to predict drying rate curves for a cloth slab of 160 layers of muslin cloth. A vaporisation zone recedes into the drying body leaving a practically dry region below the surface.

28. Drake, L. C. Ind.Eng. Chem. 41. 780-5 1949
PORE SIZE DISTRIBUTION IN POROUS MATERIALS. App. & technique for measuring porosity of materials of pore-diameter 200-350 A, using high pressure 25-60,000 p.s.i. A mercury porosimeter is described. Experimental results with Silica gel and alumina.

29. Dreisbach, R. R. Ind. Eng. Chem. 41(8) 1749-50 Aug. 1949
CORRECTION FACTOR FOR LATENT HEAT. A method for calculating the Haggenmacher correction factor for L.H. by a modified Antoine equation.

30. Dumanskii, A. V. Doklady Akad. Nauk S. S. S. R. 64. No. 4 p. 537 1949
THE HEAT OF WETTING AND SWELLING.

31. Elenbaas, W. J. Applied Physics 19(12) Dec. 1948. Philips Res. Rep. 3, 338, 1948. De Ingenieur 60(7) 21-34. 13/2/48
DISSIPATION OF HEAT BY FREE CONVECTION. A body differing in temperature from its surroundings loses energy not only by radiation but also by conduction and convection. The general laws governing the latter dissipation of heat are investigated. The many quantities governing this transfer may be combined into a few dimensionless numbers by means of similarity considerations. This leads to an important simplification and facilitates the survey of experimental and theoretical results. First the above-mentioned considerations are applied to bodies that may be characterized by one linear dimension only (the vertical plate, the horizontal cylinder, the sphere) and further, to bodies characterized by two such quantities (the vertical cylinder of finite height, cooling ribs, the inner surface of vertical tubes).

32. Emmett, P. H. Ind. Eng. Chem. 37. 639-644. 1945
GAS ADSORBENTS. MEASUREMENT OF SURFACE AREA. A critical Review of published methods concerning the adsorption of gases by solid adsorbents at temperatures close to the boiling points of the gases. The conclusion is that the low temperature adsorption isotherms of a gas such as nitrogen afford the simplest method of measuring surface area of finely divided adsorbents.

33. Ernst, R.C., Ardern, D.B., Schmied, O.K., Tiller, F.M. Ind. Eng. Chem. 30(10) 1119-22 1938
DRYING COMMERCIAL SOLIDS. The drying of prussian blue, taken as a typical gelatinous solid that adheres firmly to the drying tray, does not exhibit the normal constant and falling rate periods. A zero rate between the two periods indicates capillary force control at that stage. Vacuum drying diminishes the period of zero rate, and at higher temperatures and higher vacuum, the zero rate did not exist.

Contd. on p.7.

This type of solid should be dried on screens or rotary dryers. the drying curves shew for the first time the relation between air and vacuum drying of solids.

34. Ewald, Posehl & Prandtl Blackie & Son 1936, p.367
THE PHYSICS OF SOLIDS AND FLUIDS.

35. Fishenden, M. Saunders, O. A. Mech.World, 1945, 119, 135-6
CONVECTION AND RADIATION. PART I AND II. The first part explains the necessity for using simplified formulae in solving practical problems on heat transfer. A list of symbols is given. In the second part curves showing coefficients of convection for flow round a single cylinder are given and allowances which should be made when considering various systems of tubes in banks are explained. The convection resulting from flow through a tube is illustrated and a curve is given showing the coefficients of convection for this case.

36. Fisher, E. A. Proc.Roy.Soc.1923, A. 103. 139-161. 664-675
SOME MOISTURE RELATIONS OF COLLOIDS. 1. A comparative study of the rates of evaporation of water from wool, sand and clay. 2. Further observations on the evaporation of water from these materials. The results are given of excellent experimental work and drying rates, shrinkage, effect of thickness etc. See also J. Agric. Science 13, 121, 1923.

37. Fisher, E. A. J.Agric.Sci. 13. 121-143. 1923
SOME FACTORS AFFECTING THE EVAPORATION OF WATER FROM SOIL. An investigation of two factors, available surface for evaporation to proceed, and the vapour pressure - water content relation as applicable to textile materials and soil. Methods based on Keen's investigation, 6 456-1914 this Jul.

38. Fisher, E. A. J.Agric.Sci. 14. 126-132, 1924
A NOTE ON SOIL SHRINKAGE. A discussion of the work and conclusions of Haines 13 296, 1923.

39. Fisher, E. A. J.Phys.Chem. 28. 360-7. 1924
THE FREEZING OF WATER IN CAPILLARY SYSTEMS. Previous work rests on the assumption that the density of water in these systems is the same as that of water in bulk. The author argues that this is not necessarily the case, and that until this point is cleared up by further experimental work, the conclusions of previous work cannot be accepted on the basis of the methods adopted.

40. Fisher, E. A. Proc.Roy.Soc. A. 105, 571-582, 1924
THE DISCONTINUITY OF THE DRYING PROCESS. Results of experimental work on the drying of wool fabric over sulphuric acid. Tabulated results, and discussion of the characteristic drying curves for various materials.

41. Fisher, E. A. Flour Millers R.A. J.Agric.Sci.17.407-419 1927
SOME FACTORS AFFECTING THE EVAPORATION OF WATER FROM SOIL. The discontinuity of the drying process. A review of the factors affecting rate of loss of moisture, external and internal factors. Examples of irregular rate curves.

42. Fisher, E. A. J.S.Chem.Ind.17(48)1935.Soc.Chem.Industry
Chem.Eng.Group & Yorkshire Section-
Advance Paper mtg.Apr.5 1935 p.3-8.
Textile mnfr. 61(731)p.449 471-2.1935
SOME FUNDAMENTAL PRINCIPLES OF DRYING. Mathematical analysis of factors governing rate of evaporation of water from any kind of material; essential features in design of drying equipment Bibliography. Paper by Horgan in same program gives new data on Rotary Dryers.

43. Foster, A. Discuss.Forad.Soc.No.3,pp.41-50 1948
PORE SIZE AND PORE DISTRIBUTION.

44. Freundlich, H. Methuen.London.4th Impr.1932
COLLOID AND CAPILLARY CHEMISTRY. Transl. from German by H. S. Hatfield.

45. Frith, J. & Buckingham, F. Engineering 134,460-3(1932)
THEORY OF DRYING. The drying power of air depends on the vapor-pressure difference between liquid water and water vapor in the air. The use of the wet-bulb thermometer graduated to read total heat per lb. of a mixture of air and water vapor is advocated.

46. Gardner, W. Soil Science 7 313-319 1919
THE MOVEMENT OF MOISTURE IN SOIL BY CAPILLARITY. Analyses the movement of water in relation to the packing of particles and the water wedges between them.

47. Gardner, W. Soil Science 10 103-126 1920
A CAPILLARY TRANSMISSION CONSTANT AND METHODS OF DETERMINING IT EXPERIMENTALLY. A theoretical discussion of soil moisture movement, mathematical analysis and discussion of laboratory experimental work. Results are presented graphically. A capillary transmission constant is defined.

48. Gardner, W. & Widtsoe J. A. Soil Science II.215-232 1921
THE MOVEMENT OF SOIL MOISTURE. A mathematical development of the problem of soil moisture movement with experimental data in graphical form. (1) The inherent moisture conductivity in an ideal soil is independent of the moisture content. 2. The capillary potential is a linear function of the reciprocal of the moisture content.

49. Gilliland, E. R. Ind.Eng.Chem.30(5)506-514 1938
FUNDAMENTALS OF DRYING AND AIR CONDITIONING. The basic equations for rate of heat and mass transfer are reviewed. The mass transfer coefficients are considered in the light of the film and turbulent-core concepts as well as on the basis of empirical dimensional equations. An analogy is drawn between heat and mass transfer which does not involve the inclusion of the analogy to fluid friction. In the case of drying, the problem is complicated by the lack of knowledge of the mechanism of fluid motion through solids. Drying rates, constant and falling rates are discussed.

50. Guiems, R. Energie, Jan.-Apr. 1947, vol.6, 11-16
DRYING PROBLEMS. A study of the physico-chemical phenomena of drying by heating (conduction, convection and infra-red radiation) and by absorption and adsorption methods.

51. Gurnham, C. F. & Masson, H. J. Ind.Eng.Chem., 1946, 38, 1309-1315
FIBROUS MATERIALS: EXPRESSION OF LIQUIDS. The separation of solid-liquid mixtures by expression has been investigated theoretically and experimentally. The liquid content of a batch of material while it is under pressure can be measured by determining the total volume and deducting the solids volume, the latter being computed from known weight and density. When pressing is continued to equilibrium at a fixed pressure, the relation between pressure, P, and sample volume, V, is given by the equation $dP/P=Ad(1/V)$, which can be integrated to $\log P=a+b/V$. According to this theory $\log P$ plotted against $1/V$ for any experiment should give a straight line. Experiments were made with paper pulp, sawdust, woollen yarn, absorbent cotton, wool felt, and asbestos fibre; the materials were pressed dry and wetted with water and various mineral oils. With a few exceptions all the experimental curves are close to straight lines. The effects of sample size, liquid phase, and solid phase are discussed.

52. Haines, W. B. J.Agric.Sci.13.296-310 1923
THE VOLUME CHANGES ASSOCIATED WITH VARIATIONS OF WATER CONTENT IN SOIL. Various hypotheses are investigated and the relations with ceramic clay pointed out.

53. Haines, W. B. J.Agric.Sci.17.264-290 1927
A FURTHER CONTRIBUTION TO THE THEORY OF CAPILLARY PHENOMENA IN SOIL. A discussion of capillary forces in soil and the possible methods of packing. Description of experimental work to measure the "pull" or capillary forces of massed particles of various shapes and sizes. The "suction" forces operate over a considerable moisture range.

54. Haines, W. B. J.Agric.Sci.20.97-116 1930
THE HYSTERESIS EFFECT IN CAPILLARY PROPERTIES, AND THE MODES OF MOISTURE DISTRIBUTION ASSOCIATED THEREWITH. A description of

experimental work to measure the capillary forces in a packed solid. (See later work by Newitt, Oliver, 1950.

55. Hendry, R. & Scott, A. W.   J.Inst.Fuel p.286-294 Nov.1950
SOME FUNDAMENTAL ASPECTS OF AIR-DRYING OF SOLIDS.   Part 1. The psychrometric Chart.   Part 2. Presentation and application of experimental drying data.   Part 3. Correlation of experimental data. The paper reviews a few of the problems involved in the air-drying of solids and the methods available for solution of these problems. The properties of air-water vapour mixtures are summarised.   The application of experimental data to the calculation of drying times in full scale dryers.

56. Hinchley, J. W.   Ind.Chemist 5 32.Jan.1929.Conference on Drying 1928.Inst.of Chem.Engrs.Trans.6 127-130 1928
DRYING BY PRESSURE.   Abstract.   Depends on the volume of voids. Pressure drying of Pigments (by Cloth), peat graphite powder.   Most uncrushed materials have voids of 30-40%.   Therefore hard materials are not likely to press to less than 30%.   The opportunity for pressure drying is with hollow and plastic particles and materials. Performance curves are given.   See also under "Ceramics".

57. Hirsch, M.   Refrig.Engineering 51.331-4.Apr.1946
DRYING AND FREEZING.   Deals with aspects which are common to preservation by drying and by freezing.   Vapour pressure conditions for liquid and frozen solutions and a universal method of representing equilibrium conditions is suggested.

58. Hirst, W.   Discuss Farad Soc.No.3.22-28 1948
THE MECHANICAL INTRACTION BETWEEN MOBILE INSOLUBLE ADSORBED FILMS, CAPILLARY CONDENSED LIQUID AND FINE STRUCTURED SOLIDS.

59. Hirsch, M.   Zimmerman, Zurich, Publication pending
THE PHYSICS OF DRYING.

60. Horgan, J. T.   Trans.Inst.Chem.Engrs.6.p.131-144.Conf. 6/12/1928
ROTARY DRYERS. includes 4 curves of data on drying clay cubes.

61. Hougen, O. A.   Chem.Met.Eng.,1940,47,15-17
TYPICAL DRYER CALCULATIONS.   Worked examples are given of the calculation of the dryer time during the constant-rate period for a granulated solid carried on trays with and without insulation on the sides and bottom, and for a sheet material on a drum dryer.   (From Brit. Chem. Physiol. Abst. B. 1940, 179).

62. Hutchison, H. P., Nixon, I. S., and Denbigh, K. G. Discuss. Farad. Soc. No. 3 86-93 1948
THE THERMO-OSMOSIS OF LIQUIDS THROUGH POROUS MATERIALS.

63. Kamei, S. & Sedohara, T. J. Soc. Chem. Ind. Japan 35, 147-61 (1932)
DETERMINATION OF EQUILIBRIUM MOISTURE OF RAW MATERIALS OF CHEMICAL INDUSTRY. Equil moisture was detd. for clays, porcelain bodies, soaps, and woods by means of R. E. Wilson's app. Curves expressing the relation between the equil. moisture and the relative humidity (the ratio of the partial pressure of the water vapor to that of satd. vapor) are S-shaped. The equil. moisture at a given relative humidity diminishes slightly with rise of temp. S. Rondo.

64. Hobson, M. & Thodos, G. Chem. Eng. Projr. 47.7.370-5.1951
MASS TRANSFER. LAMINAR FLOW OF GASES THROUGH GRANULAR BEDS.

65. Kamei, S. & Sedohara, T. J. Soc. Chem. Ind. Japan 37, 68-77B (1934) Feb.
UNTERSUCHUNG UBER DIE TROCKNUNG FESTER STOFFE III - IV.

66. Kamei, S. & Sedohara, T. Soc. Chem. Industry, Japan-J v 37 n 10 Oct. 1934 p 1399-1404; see also German abstract in supp. binding of same issue p. 626B-30B
UNTERSUCHUNG UBER DIE TROCKNUNG FESTER STOFFE VI. Investigation on drying of solids; relation between rate of drying and direction of air; tests carried out with kaolin and feldspar.

67. Kamei, S., Mizuno, S., & Shiomi, S. et. al. J. Soc. Chem. Ind. Japan 38, 456-73 943/53. 1074-89, 1210-18, 1935
INVESTIGATION OF THE DRYING SOLID SUBSTANCES. Cause for decelerated rate of drying, the drying of alumina, drying shrinkage of clay, surface coefficient and critical water content of clay during drying, soap drying.

68. Kamei, S., & Shiomi, S. J. Soc. Chem., Ind. (Japan) 40, 251-7B (1937) July.

DRYING OF SOLIDS.

69. Keen, B. A. J. Agric. Sci. 6 456-475 1914
THE EVAPORATION OF WATER FROM SOIL. The evaporation from soil is a more complex phenomenon than that from sand or silt. Due to the colloidal properties of soil clay. Method of experiment was established by Keen (and used later by E. A. Fisher). A complete explanation demands a knowledge between vapour pressure and water content, hitherto unknown for soil.

70. Keen, B. A. Longmans 1931
THE PHYSICAL PROPERTIES OF THE SOIL.

71. Ketteacker, L. Gesundheits-Ingenieur 54 1931 693
DRYING OF POROUS MATERIALS.

72. Keyes, F. G. J.Chem.Phys.,1947,15,602-612
WATER: THERMODYNAMIC PROPERTIES. Correlation of all new data on the properties of water in the region below 200°C., using J. A. Beattie's determinations of the relation of the International temperature scale of 1927 to the thermodynamic scale, discloses a high degree of thermodynamic consistency from 0° to 150°C. between thermal data, vapour pressures, and equation of state information. The proposed vapour pressures over the temperature range are probably accurate to $\pm 0.002^{\circ}$C. Tables of vapour pressure, pressure-temperature derivatives, essential temperature-scale magnitudes, enthalpies, and entropies are given. An equation of state for steam is reported from 0° to 460°C., valid for low pressures and based on the ensemble of volume data and enthalpy pressure coefficients available. There are 23 references to the literature.

73. Kirschbaum, E. Z.V.D.I.Verfahrenstech.(3)84-87.1943
THEORETICAL PRINCIPLES OF EVAPORATIVE DRYING. Basic equations are developed and related with Mollier diagram of enthalpy V.S., moisture content. An example of a drum dryer is presented in detail. Chem. Abstr.44 7595. 1950.

74. Klemensiewicz, Z. Nature 1/10/49.164.4170.p.589
Quotes work by others which shews that the conductivity of powders is due to surrounding air convection. Thus the presence of powders would improve any dewar flask efficiency by reducing convective currents and radiation and by absorption of remaining gases.

74a. Knock, C. Paul Parey Berlin.1927.234pp.
THE DRYING OF COLLOIDAL LIQUIDS, ESPECIALLY MILK AND OTHER FAT AND PROTEIN CONTAINING MATERIALS. A review of world patents literature, methods and apparatus. (Transl.)

75. Koeniger, W. Chemische Fabrik v 8 n 19/20 May 15 1935 p.171-9
REFRIGERATING ENGINEERING. LABORATORIES. DAS FORSCHUNGSINSTITUT FUER KAELTETECHNIK UND TROCKENTECHNIK AN DER TECHNISCHEN HUCHSCHULE BERLIN. Research laboratory for refrigeration and drying technology at Berlin Institute of Technology; illustrated description of layout and equipment of laboratory, affording means for extensive research in field of refrigeration and preservation, drying, cooling, evaporation and related fields.

76. Krevelen, D.W. van & J.Soc.Chem.Ind., 1949, 68, 59-66
Hoftijzer, P. J.
GRANULATED MATERIALS: DRYING. Investigations on the factors governing the rate of drying of single granules are described and experimental data are presented. Granules of wet marl, suspended from the beam of a torsion balance, were dried in a current of dry air. Two rate periods were observed; during the first the rate of drying remained constant, during the second it decreased. Equations are derived for the rate of drying during the second stage which agree with experimental results. Dimensionless empirical equations are also derived for the two drying stages. With granules of nitrochalk fertilizer, dried in the same apparatus, the rate of drying decreased rapidly at first but soon reached a constant value. The initial rapid decrease was ascribed to a filling of the pores by ammonium nitrate. When the rate became constant drying took place exclusively by diffusion of water through a thin crystal film which had an average thickness of 10-3 to 10-5cm. In this period the rate of drying only depended on the temperature and size and structure of the granule. The mechanism of drying therefore changes fundamentally when the wet granule contains a soluble salt which crystallises during drying.

77. Krischer, O. Z. Ver.deut.Ing., 1939, 83, 958-60
THEORY AND EXPERIMENTAL STUDY OF THE DRYING OF POROUS SUBSTANCES IN AIR. After briefly reviewing fundamental principles of moisture movements in porous substances the author discusses theoretical and experimental investigations of the mutual relations between movements of liquid and diffusion of vapours in the drying of porous materials. Typical drying curves are given for various types of brick, sand, etc.

78. Krischer, O. Chem.Apparatur, 1939, 26, 17 & 36. Warme-u.Kaltetech., 1939, 41, 139 (Abstr.). Bull. int.Inst.Refrig., 1942, 23, 107
PHYSICAL PROBLEMS IN THE DRYING OF SOLID POROUS SUBSTANCES BY MEANS OF GASEOUS DEHYDRATING AGENTS. (transl.title). Gives a general account of the present state of knowledge as regards the problem of drying wet substances in a gaseous dehydrating agent, from the mathematical and physical points of view.

79. Krischer, O. Chem.Fabrik. 1939, 12, 23-5
RECENT RESULTS OF THE DRYING OF SOLIDS IN AIR. For material, the capillaries of which are not too fine, the course of drying under certain air conditions of temperature, rate of flow and humidity can be predicted if the grain size, "diffusion and capillary behaviour" are known. From I.C.I. Abst.

80. Krischer, O. Chem. Technik, 1943, 16, 117-121, 129-132; Brit. Abstr. B. I. 1945, 313
THERMODYNAMICS OF THE DRYING OF SOLIDS. By the application of suitable combinations of drying conditions, e.g., humidity of surroundings, ambient temp., and intensity of supply of heat to the material to be dried, a variety of types of moisture-distribution fields can be produced in the material. Rise of temperature or reduction of external pressure can be used to increase the rate of drying. The rate of passage of air over the material is generally of minor importance. A mathematical treatment of different drying processes for different types of material in terms of their termoydynamic properties is given, leading to a method of calculating the course of drying in porous materials from physical consts.

81. Kroell, K. Z. Ver. Deut. Ing. 80, 958-62 (1936) Aug.
LAWS FOR THE DRYING OF SOLIDS.

82. Lewis, W. K. Ind. Eng. Chem. 13, 427-30 May 1921
THE RATE OF DRYING OF SOLID MATERIALS. Suggested diffusion mechanism to explain the movement of moisture in solids.

83. Luikov, A. V. Khimstroi 6, 224-30 (1934)
THE THEORY OF DRYING PROCESS. A discussion with mathematical treatment.

84. Luikov, A. V. Kolesnikov, A. G. J. Tech. Phys. (USSR) 2, 708-25 (1832)
THEORY OF THE DEPTH OF THE EVAPORATION SURFACE IN THE DRYING OF FLAT BODIES.

85. Lykov, A. V. Kolloid Zhur. 10, 289-304 (1948)
THEORY OF THE KINETICS OF THE PROCESS OF DRYING OF COLLOIDAL CAPILLARY-POROUS BODIES. The math. of drying porous bodies is developed in 44 equations. The curve "rate of drying against percentage moisture in the body" shows 2 "crit. points" the first of which indicates that the zone of evaporation starts moving inside the body or that the surface H_2O ceases to have the vapour pressure of satd. H_2O, while the 2nd corresponds to the boundary between the capillary and adsorbed moisture. The theory is illustrated by drying curves of a textile fabric, wheat dough, ceramic plates, bread, and sand.

86. McCready, W. & McCabe, W. L. Trans. A. I. C. E. 131-60. 1933
THE ADIABATIC AIR DRYING OF HYGROSCOPIC SOLIDS.

87. McDermott, P. F. Refrig. Eng. g. 42(2) 103-123 Aug. 1941
MOISTURE MIGRATION - A SURVEY OF THEORY AND OF EXISTING KNOWLEDGE. The effects of diffusion and of hygroscopicity (R.H.) in a porous wall.

88. Malmquist, L. Trans. Roy. Inst. Technol. Stockholm No. 15 1-52 1948. Bull. Br. Sci. Inst. Res. Assn. 3 329 1948 B.I 533 July 1949

TEMPERATURE MEASUREMENTS IN HIGH VELOCITY GAS STREAMS. Method, Theory and Illustrations. Error is less than 0.3% at super-sonic speeds.

89. Markham, A. E. Indus. & Eng. Chem. v 29 n 6 June 1937 p. 641-2

INTEGRATION OF DRYING EQUATION AT CONSTANT TEMPERATURE. Integration of differential equation for variable conditions using inert gas to show relationship between W and delta H.

90. Marshall, W. R., Hougen, O. A. Trans. Amer. Inst. Chem. Engrs. 38 91-121 1942

DRYING OF SOLIDS BY THROUGH CIRCULATION. See under "Drying General"

91. Masson, O. and Richards, E. S. Proc. Roy. Soc. A. 74. 230-254. 1904-5. A. 78. 412-429. 1906-7

ON THE HYGROSCOPIC ACTION OF COTTON. Experimental work on the equilibrium conditions of cotton materials at various atmospheric humidities. Definite relations are established, irrespective of the method of packing. A new method of hygrometry is suggested, based on the rise of temperature when first exposed to moist air.

92. Newitt, D. M. Pearce, J. F. and Oliver, T. R. C. & I. Report of Paper to Instn. of Chem. Engrs. p. 92 5 Feb. 1949

THE MECHANISM OF AIR DRYING OF SOLIDS. Using a modified Poiseulle equation, the frictional forces within a bed of spherical particles have been calculated, and hence the relative magnitudes of gravitational, capillary, and frictional forces for different particle sizes could be assessed. Authors conclude that for large particles gravity predominates and movement of water to the surface is small. Therefore most drying will occur in the falling rate period. With smaller particles capillary forces will predominate and with very small ones, frictional forces become important. From these conclusions the influence of the drying rate and depth of bed on the critical moisture content was deduced for particles of different sizes and the deductions confirmed experimentally. See also "Measurement of Capillary Forces in Drying Granular Solids". T. R. Oliver. J. Imp. Coll. 5 1949 in which the experimental technique is described.

93. Nutting, P. G. J. Franklin Inst., 1944, 238, 177-184

SOLIDS: DRYING: THEORY. As a contribution to the problem of drying, a general relation is developed between the energy of retention of fluids by solids, and the pressure and temperature, by thermodynamic methods, applicable even to cases where the energy varies with the amount of fluid present. The three classes of experimental data on adsorption, namely, heat of wetting, change of weight with temperature, and change of weight with vapour pressure, are reviewed, their interpretation in the light of thermodynamic theory is discussed and relations between energy of change of phase and amount of fluid retained are deduced.

94. Oliver, T. R. Jnl. Imp. Coll. Chem. Eng. g. Soc. 5. 81-97. 1949
MEASUREMENT OF CAPILLARY FORCES IN DRYING GRANULAR SOLIDS. Thesis. The results of experimental work shew that for coarser materials, the movement of water is by capillary action and may be predicted from a consideration of these forces. In the finer solids, the capillary forces are modified by vaporisation of the water within the solid itself and the rate of water movement is largely controlled by the rate of vapour movement to the surface. Frictional resistance to fluid flow is not of sufficient magnitude in any of the solids to affect drying characteristics. The capillary theory is discussed in relation to typical cases, the results of previous work are reviewed and the methods used in the present investigation with their limitations are fully described.

95. Parmelee, G. V. & Huebscher, R. G. Amer. Soc. H. & V. Engrs. Res. Bull. 53. No. 3. 11/1947
FORCED CORRECTION HEAT TRANSFER FROM FLAT SURFACES. PART 1. SMOOTH SURFACES.

96. Pearse, J. F. Thesis for Ph. D. Degree. 1948. Univ. Ldn. Imp. Coll. Ldn.
A STUDY OF THE MECHANISM OF DRYING OF GRANULAR SOLIDS. 70 pp. This work, together with that of T.R. Oliver is an investigation into the behaviour of particles in the range 10 mu to 500 mu, in an endeavour to close this gap.

96a. Perry, J. H. Chemical Engineers Handbook 1950. pp. 801-884
THE DRYING OF SOLIDS. Theory and fundamental concepts. A detailed treatment of the constant and falling rate periods, methods of correlating drying data, humidity charts, drying data for various solids, types of dryers illustrated the principles and mechanism of spray drying and of other types of dryers. A tabular classification of commercial dryers. The principles of gas drying and the properties of desiccants.

97. Piccardi
SURFACE TENSION. See under Milk.

98. Poole, R. Heat & Vent. Engr. 20. 55-61. Aug. 1946
AERODYNAMICS FOR HEATING AND VENTILATING ENGINEERS.

99. Prandtl, L. FIAT Rev. German Sci., Hydro- and Aerodynamics, 1948, 55-78. (In German)

TURBULENT FLOW: REVIEW OF GERMAN INVESTIGATIONS. A Literature review, containing 69 references, is given of German war-time studies on turbulence in the presence of walls, free turbulence, measurements of turbulence, heat transfer, geophysical applications, and some fundamental problems of turbulent flow.

100. Preston, J. M. & Chen, J. C. J. Soc. Dyers & Colourists, 1948, 64, 60-64

TEXTILES DRYING MECHANISM. The mecnanism of moisture transfer has been investigated in the drying of textiles by conduction, convection, radiation and dielectric loss heating, by studying the transfer both of water (and other liquids) and of solutes. With the exception of very slow drying at room temperature and high-frequency drying, all these drying techniques give rise to marked migration of solute. This shows that the solvent moves as a liquid towards the source of drying energy. When the liquid approaches the free surface where the energy enters the fabric it becomes vaporised, deposits the solute and leaves the surface fibres dry. Further liquid is then attracted to the dry surface fibres by capillary action, and liquid from the inside of the fabric feeds the surface layer under a liquid concentration gradient set up by the evaporation of liquid near the surface. In radiation and convection drying, vapour passes into the atmosphere during this time, but as the vapour pressure gradient falls inwards as well as outwards, vapour also passes inwards. In conduction drying, all the vapour must be carried into the fabric. Owing to the large surface area of the fibres, the heat in the vapour is rapidly transferred to the fibres. Liquid is thus produced which can feed back towards the surface to start another cycle. Fibre temperature rises slowly and diffusion further inward continues until a steady temperature gradient is established. Constant loss occurs from the cool side due to convection, radiation and vaporisation. Photographs showing dye migration are included in support of these theories.

101. Procat, F. V.D.I. Zeit., vol. 74, no. 51, Dec. 20, 1930, pp. 1729-1734, 14 figs.; see also brief translated abstract in Iron, Steel and Indus. Fuel, No. 37, Jan. 1931, p. 3.

KOHLENENTWAESSERUNG UND WASSERKLAERUNG DURCH SCHLEUDERN (DE-WATERING OF COAL AND REMOVAL OF WATER BY CENTRIFUGING. Mathematics of process of separating solids and liquids by centrifuging, and results of experiments to determine influence of variations in centrifugal force, in duration of centrifuging, and in particle size, on degree of de-watering; number of centrifuges and their operating results, with particular reference to de-watering of fine coals.

102. Rowley & Lund Univ.Minnesota Expt.Stn.Bull.35.274-6. 1945
MEASUREMENT OF DRYING CHARACTICS OF SOLIDS.

103. Roy, M. M. Mukherjee, R. R. and Sen, M. K. J.Text Inst.41.7 T.249-254 July 1950
THE AIR FLOW METHOD OF MEASURING THE SPECIFIC SURFACE OF JUTE. Application of the method is originally due to Carman. J.Soc.Chem. Ind.1938.57.225.1939-58.1, who established its suitability for powdery and granular substances e.g. carbon black, cement, sand; and others employed the method for wool, cotton and rayon fibres and obtained values in agreement with those obtained microscopically. 11 Refs. The method is based on the Kozeny equation, a simple apparatus, with kerosine manometer, liquid paraffin water seal in the aspirator for passing air through a brass tube of the material.

104. Scott, A. W. Fuel & the Future 1948,pp.267-276
THE DRYING OF FOODSTUFFS AND WASTE PRODUCTS. The paper deals largely with the theoretical aspects of the various air circuits which can be used. Principles of evaporation into an air stream. Single stage air dryers, counter flow, rotary, pneumatic, parallel flow with recirculation, counter flow with inter-stage heating. Thermal Efficiencies. This is a very clear exposition of the principles of drying by various methods and contains a simplified mathematical treatment.

105. Schofield, R. K. & Talibuddin, O. Discuss Farad Soc.No.3.51-55 1948
MEASUREMENT OF INTERNAL SURFACE BY NEGATIVE ADSORPTION.

106. Sheahan J.Imp.Coll.Chem.Eng.Soc.1.32-8:1945
CONSTANT RATE OF DRYING. Constant rate found to be only approximately constant (for whiting of various particle sizes on trays). Found a slight decrease in rate for decreasing moisture content. No conclusion respecting size of particles.

107. Sherwood and others. Industrial & Eng.Chem..

1929	Vol.21	Part	I.	p.12 - 15.
"	"	"	II.	p.976 - 979
1930	" 22	"	III.	p.131 - 136
1932	" 24	"	IV.	p.307 - 310
1933	" 25	"	V.	p.311 - 315
"	"	"	VI.	p.1134 - 1135

I. Classification. 4 ways of drying. General Equations. Curves. Applications to clay and soap slabs.
II. Effects of adjoining dry surfaces, radiation from surroundings, air velocity. Falling rate period. Curves. Equations.
III. Mechanism of drying pulp and paper. Curves. Experimental Data.

IV. Application of Diffusion Equations. Curves. Appl. to Clays.
V. Mechanism of drying clay, sands and ceramic plate. Curves representing rates of drying v.s. R.H.
VI. Diffusion Equations for the Period of constant drying rate. (See separate references).

108. Sherwood, T. K. Ind. & Eng. Chem. 22. 130-5. 1930
THE DRYING OF SOLIDS III. Mechanism of Drying PAPER AND PULP. Sulphate pulp slabs. Moisture gradients. Results of experimental work presented in a series of curves.

109. Sherwood, T. K. Trans. Amer. Inst. Chem. Engrs. 32. 150-158. 1936
THE AIR DRYING OF SOLIDS. A general description of the mechanism of drying and effect of air velocity, moisture movement in solids, falling rate period, dryer design and a table of data and drying characteristics for various solids. 34 Refs.

110. Sherwood, T. K. & Comings, E. W. Ind. Eng. Chem. 1933. 25. 311
THE DRYING OF SOLIDS V. Mechanism of Drying Clays and Sands. Ceramic Plate. Curves for drying clayware under different conditions. Usual sharp critical Moisture Content. Application of Diffusion equations. See also Heating, Piping and Air-Conditioning 5. 187. Apr. 1933.

111. Shuttleworth, R. & Bailey, G. L. J. Discuss Farad Soc. No. 3 pp. 16-21. 1948
THE SPREADING OF LIQUID OVER A ROUGH SOLID.

112. Smith, A. J. M. U.K. Progress Reports. Dehydration 1943. D.S.I.R. and Min. of Food X(3) pp. 1-44
NOTE ON PHYSICAL ASPECTS OF DRYING AND SOME DRYING CHARACTERISTICS OF FOODS. 1. Water Transfer from an evaporating surface. 2. The Drying of Solids. 3, 4, and 5. Data on the drying characteristics of Fruits, Vegetables, and Minced Beef. 6. Progressive Drying. Appendix. Fuel Economy in Dehydration.

113. Spooner, W. W. J. S. D. C. 55. 290-302. 303-308. 1939
SOME PRINCIPLES OF DRYING.

114. Stacey, A. E. Jr. J. Am. Cer. Soc. 8. 457. 1925
THEORY OF EVAPORATION - ETC. Quotes data of Carrier, Coffey & Horne, and Hinchley and Himus on rate of vaporization. Gives two rate curves for clay.

115. Straight, H. R. Chem. Met. Eng. 40, 410-3 1933)
THE USE OF DE-AIRING FOR CLAYS AND OTHER PLASTIC PRODUCTS. Quotes Sherwood's data on drying of wood.

116. Strock, C. Industrial Press New York. 570 Paper 193 Charts & illustrations 317 tables $7
HEATING AND VENTILATING ENGINEERING DATA BOOK. Short review in Jnl. of Inst. of H. & V. Engrs. 16 No. 154 p. 125 May 1948.

117. Swain, P. W. Power, Sept. 1945, 89, 607-8
COMBUSTION DATA IN CONVENIENT FORM. Three tables are presented:- (1) Weight and volume of one mol. in lbs. and mol. volume units for various substances commonly occurring in combustion reactions. (2) Mol. weight, weight/cub. ft., vol./lb., nature and heating value (if any) of common fuels and combustion products. (3) Air required for and combustion products of common fuels for one mol., one cub. ft. and one lb. of the fuel. Two examples, one for gas and one for coal are included to illustrate the use of the tables.

118. Tamura, M. Soc. Mech. Engrs. Japan- J v 36 n 189 Jan. 1933 p. 27-30
EXPERIMENTAL RESEARCH ON SOME TERMS EFFECTED BY HEATING TEMPERATURE IN HIGH-TEMPERATURE DRYING. Attempt is made to obtain relation between time for drying and heating temperature; apparatus used is set of thermo-balance and heating furnace; samples were porcelain balls having diameter of 84 mm. (In Japanese).

119. Tamura, M. Soc. Mech. Engrs., Japan - J v 37 n 209 Sept. 1934 p. 606-8
EXPERIMENTAL RESEARCH ON SOME TERMS AFFECTED BY HEATING TEMPERATURE IN HIGH TEMPERATURE DRYING.

120. Tamura. M. Soc. Mech. Engrs. Japan -- Trans v 2 n 6 Feb 1936 p 138-48
THERMOSTATICAL RESEARCH OF HIGH TEMPERATURE DRYING. Two empirical formulas for relations between ball diameter, heating temperature, time required for drying and between ball diameter, heating temperature, heating time and depth of dry area of externally heated wet porcelain ball, are derived; rate of drying and efficiency of furnace with respect to typical heat balance are calculated. (In Japanese with brief English abstract.)

121. Thomas, C. W. A. S. M. E. (1933) Dec.
DRYING - FUNDAMENTALS OF METHOD.

122. Thomas, M. D. Soil Science II 409-433. 1921
AQUEOUS VAPOUR PRESSURE OF SOILS. Description of apparatus and procedure for its measurement. Absorption of salts by soil. The vapour pressure - moisture curves are shewn to be rectangular hyperbolae over a wide range of moisture content, i.e. vapour pressure is proportional to the reciprocal of the moisture content.

123. Thomas, W. R. Br. Paper & Board Ind. R. A. T. /1. Dec. 1947
84 pp. 32 refs.
A SURVEY OF THE PHYSICS OF THE FLOW OF FLUIDS IN POROUS MEDIA WITH SPECIAL REF. TO THE REMOVAL OF WATER BY MECHANICAL MEANS FROM PAPER AND ITS RELATED PRODUCTS.
- Basic Relationships. Theory of Dimensions.
- Davey's Law. Its validity. Permeability of a Porous Medium. Detn. of Pore Dimensions. Specific Resistance of a porous medium.
- Application of theory to Fluid Flow through Paper. Removal by various means. See also under Paper.

124. Thomas, W. R. & Bennet W. E. Br. Paper & Board Ind. R. A. Sept. 1950 R. A. /T/19. 105 pp.
A SURVEY OF THE PHYSICS OF DRYING OF POROUS MATERIALS WITH SPECIAL REFERENCE TO THE DRYING OF PAPER. The work deals mainly with an analysis, largely mathematical, of the general principles and then with the applications to the drying of paper. Numerous references.

125. Thurston, E. F. J. Soc. Chem. Ind. 67. 7. 289-296. 1948
GAS DRYING BY CALCIUM CHLORIDE SOLUTIONS: THE MECHANISM OF TRANSFER. The results of experimental work with a laboratory packed tower to determine the respective contributions of the gas and liquid films to the transfer of water vapour. There is strong evidence to shew that gas drying by $CaCl_2$ solution is essentially limited by diffusion in the gas film. A list of 22 references.

126. Travers, M. W. Proc. Roy. Soc. A. 79. 204-5. 1907
ON THE ABSORPTION OF WATER BY COTTON WOOL. A note on the association of Prof. Trouton's results with Travers' work on the Law of Distribution where one of the phases has mechanical rigidity. Proc. Roy. Soc. A. 78 p. 9, 1906, and an extension of Trouton's work. Discussion on solid solutions.

127. Trouton, F. T. & Pool, B. (Miss) Proc. Roy. Soc. A. 77. 292-314. 1906
THE VAPOUR PRESSURES IN EQUILIBRIUM WITH SUBSTANCES HOLDING VARYING AMOUNTS OF MOISTURE. There appear to be no investigations published on the subject of the quantity of water held by absorbent substances at varying humidity. The subject is of importance to drying. The amounts held appear to depend wholly on the hygrometric state. The change in weight with R.H. follows a simple parabolic law. Thermodynamic considerations. Experimental work with wool and with sulphuric acid of various strengths is described and the results plotted.

128. Underwood, A. J. V. Ind. Chemist. 4. 463-6. 1928
THE MATHEMATICAL THEORY OF FILTRATION. 13 Refs.

129. Vassilion B. & White, J.
CAPILLARITY. See under Ceramics.

130. Walker, Lewis, McAdams　　McGraw Hill Book Co. 1937
and Gilliland
PRINCIPLES OF CHEMICAL ENGINEERING pp.612-682. A general description of drying and dryers. Fundamental principles occupy more than half the chapter. Applications of theory to design are given.

131. Watkins, C. M. &　　Trans. Ceram. Soc. 23. Oct. 1934
Butterworth
See under Ceramics.

132. Weisselberg, A., Thomas, C. W.,　　Trans. Amer. Soc. Mech. Engrs. 57(1)
and Olive, T. R.　　41-47 1935
CLASSIFICATION OF DRYING, INCLUDING GRAPHICAL ANALYSIS OF AIR DRYING AS DEVELOPED ABROAD. The authors classify the liquids as to kind, nature and state, enumerate the means available for their removal, discuss briefly the limitations of the various dryers. A graphical method of analysing air drying is described, and by this means, terms which are now confusing are defined and the factors governing the performance of drying equipment are explained.

133. Westman, A. E. R.
PRESSURE EFFECTS. See under Ceramics.

134. Wiegerink, J. G.　　J. Res. Nat. Bur. Stds. 24. 639-644. 1940
HIGH TEMPERATURE CONDITIONING EQUIPMENT. Equipment for the study of moisture relations of materials at controlled R.H's. at temps. up to 300^0F, at R.H's. from 10 to 90% for temps. up to 212: Saturated air is passed to a working chamber at higher temp. and the R.H. adjusted thereby. Automatic control. See also under Textiles.

135. C. R. Wilke & Hougen, O. A.　　Trans. Amer. Inst. Chem. Eng. 41, 445, 1945
MASS TRANSFER IN THE FLOW OF GASES THROUGH GRANULAR SOLIDS EXTENDED TO LOW MODIFIED REYNOLDS NUMBERS. Experimental data on the transfer of water vapour from air flowing through granular solids were obtained in the range of modified Reynolds' numbers from 50 to 250. Seven different particle sizes were used. Special precautions were required to obtain reliable surface temperatures of the solid at low velocities of air flow. Places the study of drying by through circulation on a fundamental basis.

136. Welling, W. A.　　De Ingenieur 61(42)33-4. 21/10/1949.
(Follows No. 40 this J.)
DETERMINATION OF THE DEGREE OF TURBULENCE OF THE AIR FLOW. Definition and description of method by the hot wire anemometer.

137. Wildson, B. H., Bennell, D. G. R.　　Natura 135 186-7(1935) Feb. 2.
and Nottage, M. E.　　See this Bull., No. 16, P. 1
PROPERTIES OF LIQUID FILMS IN FINE-PORED SYSTEMS.

138. Wink, W. A. Ind. Eng. Chem. (Anal.), 1946, 18, 251-2
April, 1946

DETERMINING THE MOISTURE EQUILIBRIUM CURVES OF HYGROSCOPIC MATERIALS. A method has been devised for determining simultaneously sorption and desorption isotherms, which requires a minimum of uncommon apparatus, conditioning equipment, and technique. Specimens are suspended in small, closed vessels in which the relative humidities are controlled by a number of saturated salt solutions. The vessels are conveniently made from crystallising dishes, 12.5 x 6.5 cm. in size, provided with greased, ground-glass covers. The point of suspension of the sample is connected through a sealed hole in the cover of the vessel to the pan hook of a balance, the hole being unsealed for weighing. All operations are carried out in a room of controlled temperature.

139. Winterkorn, H. F. Soil, Sci., 56, 109, 1943

THE CONDITION OF WATER IN POROUS SYSTEMS. The phase diagram for water as worked out by Tammann and Bridgman has been used as a basis for analysing the physical condition of water in soil and similar porous systems. It appears that this concept leads to a ready explanation of a number of phenomena which are of considerable practical importance with regard to the stresses and strains observed in soil-water systems.

140. Zimosa, R. Abdon Rev. Ing. Quim. Univ. Concepcion (Chile) 7
121-8. 1948. Chem. Abstr. 43(9)3246. 1949

DETERMINATION OF CRITICAL HUMIDITIES IN DRYING. Apparatus and method illustrated. In the drying of spheres of Fe_2O_3 of 10 m.m. diam. in a circulating air dryer with constant heat input, the material was weighed every 10 minutes until drying was very slow, then at 15, 25 and 30 minute intervals. Curve for weight loss v.s. time. The point of inflexion is the critical humidity.

Evaporation

141.

EVAPORATION OF DROPLETS. See under Spray Drying.

142. Sci. Libr. Bibl. Series No. 353 1937

EVAPORATION FROM LARGE WATER SURFACES. 24 Refs.

143. Alty, T. Phil. Mag. 15, 82-103 (1933); cf. C. A. 27, 2359

MAXIMUM RATE OF EVAPORATION OF WATER. The Max. rate of evapn. of water was measured for surface temps. in the range - 8^0 to 4^0. The evapn. coeff. is defined as the ratio of the exptl. rate to the rate calcd. on the basis of Knudsen's equation. Its value is 0.04.

144. Boelter, L.M.K., Gordon, H.S., and Griffin, J. R. Industr. Engng. Chem., June, 1946, 38 596-600
FREE EVAPORATION INTO AIR OF WATER FROM A FREE HORIZONTAL QUIET SURFACE. Curves and equations cover the evaporation of distilled water from a one-foot-diameter surface, within the temperature limit 68^{0} and 200^{0}F., into quiet air at 65^{0} to 80^{0}F., and 54 to 98% relative humidity.

145. Brookfield, K. J., Fitzpatrick, H.D.N., Jackson, J.F., Matthews, J.B., and Moelwyn-Hughes, E. A. Proc. Royal Soc., 1947, 190A, 59-67
WATER MOLECULES: ESCAPE FROM A PLANE SURFACE INTO A STILL ATMOSPHERE. On the basis of previous theories the mechanism of the escape of molecules from a plane liquid surface is formulated. An apparatus and procedure for measuring diffusion coefficients is described. Typical results are presented. As a check upon the method, the diffusion of water vapour into still air at atmospheric pressure and at various temperatures has been measured, and the results confirm that the method described provides reliable values of the coefficient of diffusion.

146. Carrier, W. H. Ind. Eng. Chem. 13. 432. 1921
THEORY OF ATMOSPHERIC EVAPORATION WITH SPECIAL REFERENCE TO COMPARTMENT DRYERS. Data on evaporation of water from plane surfaces. The wet bulb temperature at air speed of 800ft. min.

147. Carrier, W. H. & Lindsay, D. C. Ref. Eng/II, 241-57 (1925)
TEMPERATURES OF EVAPORATION OF WATER INTO AIR. Thermodyn. treat. of drying and cooling by evaporation. Wet bulb temperature, fundamental laws involved in all drying processes. Errors in wet bulb. temp. tabulated.

148. Creagh, Koffolt, & Withrow. Trans. Amer. Inst. of Chem. Engrs. 32. 521-56 1936
THERMODYNAMIC INVESTIGATION OF THE FLASH EVAPORATION OF CONC. POTASSIUM SULPHATE LIQUOR FROM POLYHALITE. Includes a method for the flash evaporation (adiabatic) of the solvent from a solution.

149. Domingo, J. Guiler. Anales soc. espan. fis. quim. 30, 492-504 (1932), see C. A. 26, 5805
EVAPORATION FROM EXTENSIVE SURFACES.

150. Giblett, M. A. Proc. Roy. Soc. A. 99. p. 472-490 1921
SOME PROBLEMS OF EVAPORATION FROM LARGE EXPANSES OF WATER. Mathematical analysis of evaporation from large sheets of water (and ice).

151. Gilbey, A. R. & Heymann, E. Austr.J.Sci.Res.Ser.A.1.197-212 1948

Found that the fractional reduction in the evaporation rate of water by covering with an oil film was greatest at high air velocities over the surface.

152. Follansbee, R. Proc.Amer.Soc.Civil Engrs.59.254-65. 1933

EVAPORATION FROM RESERVOIR SURFACES. Rates of evaporation from reservoir surfaces in U.S. and other countries. No transfer coeffs. are given.

153. Gilliland, E. R. & Sherwood, T. K. Ind.Eng.Chem.26.516-523.1934

DIFFUSION OF VAPOURS INTO AIR STREAMS. Data are presented on rates of vaporisation of nine liquids into air flowing in a wetted wall column. The diffusional resistance to vaporisation is expressed in terms of the effective film thickness, the thickness of the stagnant gas layer which would offer the same resistance to diffusion as is actually encountered.

154. Goslin & Hammond. J.Color.-Wyo.Acad.Sci.1,No.3 31(1931)

EFFECT OF HUMIDITY ON RATE OF EVAPORATION.

155. Griffiths, E. & Powell, R. W. Trans.Instn.of Chem.Engrs.13. 173-192,1935

THE EVAPORATION OF WATER FROM PLANE AND CYLINDRICAL SURFACES. Effects of edges on turbulence,

156. Griffiths, E., Awbery, J.H. & Powell, R. W. Dep.Sci.Industr.Res.,Lond.,Rep., Food Invest.Bd.1938,P.265

WORK CARRIED OUT AT THE NATIONAL PHYSICAL LABORATORY. A report of investigations on (1) the relation between rate of evaporation and nature of air flow over a surface (including the effect of ridges), (2) the influence of films on the surface on evaporation from water, (3) determination of the diffusion of water vapour in air, and (4) physical properties of refrigerants (ethyl chloride, methyl chloride and dichlorodifluoro methane).

157. A.H.de Hass van Dorsser, H.A. Leniger, & D.A. van Meel De INGENIEUR 61(40)25-30. 7 Oct.1949 in English

PRELIMINARY INVESTIGATION ON THE INFLUENCE OF THE DEGREE OF AIR TURBULENCE ON THE RATE OF EVAPORATION FROM A FREE WATER SURFACE INTO A TURBULENT AIR STREAM.

DETN. OF THE DEGREE OF TURBULENCE OF THE AIR FLOW. By W.A.WELLING. See this J.No.42.

SUMMARY

An investigation was carried out on the influence of the degree of turbulence on mass-transfer. In a small wind-tunnel, the turbulence level was varied by using turbulence generators. The definition and measurement of the degree of turbulence is described in the Appendix. Measurements were carried out with degrees of turbulence of 1.7, 2, 3.5, 7 and 13%. The test surface consisted of a piece of blotting paper, kept wet by the arrangement shown in fig. 2 and 3. The air velocity varied from 3 to 20 m/sec. All experiments took place at room temperature. The flow of the air appeared to be considerably disturbed by the turbulence generators. By comparing the rates of evaporation only the measurement of air velocity immediately above the test surface was considered. Velocity distributions are given in fig. 4, 5 and 6. The rates of evaporation as a function of the air velocity are shown in fig. 7 and 8. The maximum increase of the rate of evaporation occurred at a degree of turbulence of about 5% and amounted to 50%. These results are compared with those of Comings, Clapp and Taylor.

As the air in driers generally has already a rather high degree of turbulence, our experiments show that only a little can be gained by increasing the degree of turbulence still further.

158. Van der Held, E. F. M. Chem. Weckblad. 34 285-9. 1949 Chem. Abstr. 4322 1949x. 25. 11. 1949

THEORY OF EVAPORATION DURING DRYING. The mechanism of evaporation is discussed in terms of molecular intertraction and boundary layer concept. Vaporisation from the surface and from the interior of liquids and solids is considered. Effects are given of material constants, thermal conditions, heat of vaporisation, grain size, capillarity and moisture retention through adsorption or otherwise upon drying operations.

159. Hickox Proc. Amer. Soc. Civ. Engrs. 70 1297-1327 1944

EVAPORATION FROM FREE WATER SURFACES. Meteorological sources. Mass Transfer. Heat transfer.

160. Hilpert, R. Forsch. Gebiete Ingenieurw. B. 2, Forschungsheft 355, 1-22. 1932

EVAPORATION AND HEAT TRANSFER FROM VERTICAL PLATES INTO STILL AIR. An analysis of results of evaporation from moistened ceramic plates etc. Experiments were also made with organic solvents.

161. Hinchley, J. W. J. S. C. I. 1922 51 242T

THE GENERAL PROBLEM OF EVAPORATION. The Imperial College formula:- Rate of Evaporation $W = 0.02 (pe - pd)^{1.2}$ where pe and pd are the vapour pressures of the water in the pan and in the air respectively.

162. Himus, G. W. Trans.Institution Chem.Engrs.1929. 7.166-177.
THE EVAPORATION OF WATER IN OPEN PANS. The presentation of much data on the rates of evaporation found at various air speeds and the derivation of a complete formula for rate of evaporation.

163. Hinchley, J. W. Himus, G. W. Trans.Inst.Chem.Eng.1924 2,57-64
EVAPORATION IN CURRENTS OF AIR. An investigation into the rate of evaporation of water in transverse currents of air of various speeds. The Imperial College formula $W = \left(\frac{Pe - Pd}{50}\right)^{1.2}$ was found to hold good for a certain range of air speeds.

164. Himus, G. W. Hinchley, J. W. J.Soc.Chem.Ind.43 840-5,1924
THE EFFECT OF A CURRENT OF AIR ON THE RATE OF EVAPORATION OF WATER BELOW THE BOILING POINT. The results of experiments at various air speeds are embodied in curves. The derived formula is compared with that of Carrier for the results obtained, 13 References including John Dalton Minutes of Lit. and Phil. Society of Manchester 5 part 2. 535-602, 1802.

165. Hine, T. B. Phys.Rev.24 p 79-91(1924)
THE RATE OF EVAPORATION OF LIQUIDS IN A CURRENT OF AIR. Chlorbenzene, M-xylene, nitro benzene, toluene used, wind from 0-15 m.p.h. 10.7% deviation from formula. 7-fold change in wind velocity. 100-fold change in v.p.

166. Jeffreys, H. Phil.Mag.35 273-280,1918
SOME PROBLEMS OF EVAPORATION. The problem of evaporation is practically one of gaseous diffusion. Mathematical analysis, and treatment of evaporation from various surfaces. For small areas or medium dimensions the rate of evaporation is proportional to radius $(a)^{1.5}$. Evaporation from the surface of a leaf.

167. Kirschbaum, E. "Der chemie Ingenieur" I Part 3,32-69. Akad Vorlag 1933
REMOVAL OF A LIQUID BY SURFACE EVAPORATION (DRYING PROCESSES).

168. Kirschbaum, E. Lise, J. Chem.Ing.Techn.21 89-94,1949
EVAPORATION AND DRYING, I. THEORETICAL. Calculated values of K = a/s. cp = l/b. cp where a = heat transfer coefficient from gas to moist surface, S = evaporation coefficient in Kg per sq. m. per hour, l = thermal conductivity of gas, b = diffusion coefficient of vapour for unit concentration gradient in the gas, are shewn to agree with the values obtained by blowing air under controlled conditions through a porous Kieselquhr tube surrounded by water. The experimental values of K were 0.936 (turbulent flow) and 0.88 (laminar flow).

169. Kolesnikov A. G. and Luikov, A. V. — Izvestiya Vsessoyuznovo Teplotechnischekovo Inst. 5-6, 550-67 (1932)

DYNAMICS OF DRYING. Theory of deepening evaporation surface in drying of flat specimens, summary of exceptional theoretical studies by Russian, American, and German investigators (in Russian).

170. Kruzhilin, G. N. — Isventia Akademii Nauk SSSR Otdelinie Teknichestkii Nauk, 1949. No. 5 May

p. 701. A generalisation of experimental data on the emission of heat when liquids are boiled under conditions of free convection.

171. Lewis, W. K. — Mech. Engg. 44 445, 1922. Trans. A. S. M. E. 44 325-340, 1922

THE EVAPORATION OF A LIQUID INTO A GAS. The author investigates the mechanism of the evaporation of a liquid into a gas as applied to such processes as drying, scrubbing etc., and establishes the formula for calculating the humidity of the air from wet and dry - bulb thermometer readings. He shows that the coefficient of heat transfer divided by the coefficient of diffusion equals the humid heat of the gas.

172. Lewis, W. K. — Mech. Engg. 55 567-8, 1933

THE EVAPORATION OF A LIQUID INTO A GAS. A correction of the equation put forward by him in 1922. (Mass. Inst. of Techn.) It must be recognised that the Wet - bulb temperature of adiabatic isopiestic evaporation of a liquid into a gas is not generally constant as hitherto assumed, although it is fortuitously so for water in air.

173. Lurie, M. Michailoff, N. — Ind. Eng. Chem. 28 345-9 1936. 13 refs.
Drying Lab. of the Thermo-Tech. Inst. Moscow.

EVAPORATION FROM A FREE WATER SURFACE. A review of early work and of equations derived by various authors for still air and forced movement. Experimental procedure of the author is described. The straight line relation between the evaporation coefficient and the air velocity is confirmed (for velocities up to 7.5 metres per second). 13 References including Dalton, Gilbert Ann. 121. 1803. See also Gesundheits Ingenieur 59. 21. 289-294. 23 May 1936.

174. Lurie, M. and Michailoff — Gesundheits-Ingenieur v 60 n 14 Apr. 3 1937 p. 202-4

DIE VERDUNSTUNG VON WASSER AUS OFFENEN OBERFLAECHEN. Evaporation of water from free surfaces. Correction of errors and discussion by K. Schultze of article indexed in Engineering Index 1936 p 434 from issue of May 23.

175. Maisel, D. S. Sherwood, T. K. Chem.Eng.Progress 46(3)131-8
March 1950
EVAPORATION OF LIQUIDS INTO TURBULENT GAS STREAMS. New data are presented. Tests were made using wetted plane surfaces, cylinders, spheres and discs, and evaporating water therefrom and other liquids (organic). Data on mass Transfer, heat Transfer and friction are correlated with Reynolds numbers, Diagram of apparatus, curves and tables are presented.

176. Maisel, Sherwood Chem.Eng.Progr. 46(4)173-5 April 1950
EFFECT OF AIR TURBULENCE ON THE RATE OF EVAPORATION OF WATER. Evaporation rates can be substantially increased by induced turbulence.

References
Chem. Eng.Progr. (46) (3) 131 1950 Maisel and Sherwood reviewed Die Ingenieur 26 Ch. Techn. (6) 1950.

Further References:-
Die Ingenieur 42 Ch. Techn. 4. 1949
" " 40 Ch. Techn. 4. 1949
Central Aerodynamic Hydraulic Inst. (U.S.S.R.) Report, 329, 1935.

177. Marboe, E. C. Chem.Eng. News 27 31 1 Aug.1949
Penn. State College pp.2198 to 2202
GAS EVOLUTION FROM SUPERSATURATED LIQUIDS.

178. Mayer, H. FIAT Rev.German Sci.,Physics of Liquids and Gases, 1948,52-57.(In German)
LIQUIDS: EVAPORATION AND CONDENSATION. A discussion is presented of German investigations of the rate of evaporation of liquids, their accommodation coefficient and the mechanism of droplet formation

179. Molstad, M.C. Farevaag, P. Ind.Eng.Chem. 30 1131-8.1938
Farrell, J.A.
THE RATE OF EVAPORATION FROM A FREE WATER SURFACE BY A PERPENDICULAR AIR STREAM. An experimental investigation shows that for a perpendicular air stream the constant was 50% above that for horizontal stream. At higher velocities only 10% above those for parallel flow found by Lurie & Michaeloff, but 30% below those obtained by Shepherd Hadlock & Brewer. No explanation is offered. Tests with air streams at 125°, 175° and 225°F. gave the same evaporation coefficients as for room temperatures. Curves relating to mass transfer are given. 19 References.

180. Nutting J.Frank.Inst.1944 238 3.177-84
THERMODYNAMIC RELATION BETWEEN FLUID RETAINED AT GIVEN T. & P. AND THE ENERGY REQUIRED TO TRANSFER TO VAPOUR PHASE. Heat required for last traces of water is in excess of heat of vaporisation.

181. Pasquill, F. Proc. Roy. Soc., A, 182, 75, 1943
EVAPORATION FROM A PLANE, FREE-LIQUID, SURFACE INTO A TURBULENT AIR STREAM. In the past the experimental study of evaporation, and the interpretation of the results obtained, have shown in general only meagre reference to the aerodynamics of the problem. The present treatment which is concerned with the evaporation from plane, free-liquid, surfaces of relatively small dimensions into a tangential air-stream, demonstrates the importance of the type of boundary layer flow. The rates of evaporation under the influence of a turbulent boundary layer are then tested against a hydrodynamical theory due to Sutton, whose theory assumes that the turbulent transfer of any entity is determined by the momentum interchange coeff.; this is shown to involve the kinematic viscosity of the diffusing medium, and leads to a functional form for evaporation which has been shown previously to be in good agreement with experimental data. Developed into a computable form, and tested against the present expts. on the evaporation of bromobenzene and against expts. on the analogous problem of convective heat transfer, the theory is now shown to predict the absolute rate of turbulent transfer in a satisfactory manner. An extension of the analysis to the relative rates of evaporation of various liquids shows that the theory specified inadequately the variation of rate of evaporation with type of liquid.

182. Pasquill, F. Quart. J. Res. Met. Soc. Ldn. 75, 1949. p. 239
A PORTABLE INDICATING APPARATUS FOR THE STUDY OF TEMPERATURE AND HUMIDITY. PROFILES NEAR THE GROUND.

183. Pasquill, F. Proc. Roy. Soc. A. 198. p. 116. 1949
EDDY DIFFUSION OF WATER VAPOUR NEAR THE GROUND.

184. Pasquill, F. Met. Res. Paper. No. 498. 1949
SOME FURTHER CONSIDERATIONS OF THE MEASUREMENT AND INDIRECT EVALUATION OF NATURAL EVAPORATION.

185. Pasquill, F. Met. Res. Paper. Ldn. No. 503. 1949
AN APPROXIMATE MEASUREMENT OF THE AERODYNAMIC DRAG OF GRASSLAND.

186. Pasquill, F. Quart. J. Res. Met. Soc. Ldn. 75. p. 249. 1949
SOME ESTIMATES OF THE AMOUNT OF DAILY VARIATION OF EVAPORATION FROM A CLAYLAND PASTURE IN FAIR SPRING WEATHER.

187. Pasquill, F. Paper Imp. Coll. 9.1.50
THE PRACTICAL WORK CARRIED OUT BY THE MET. OFFICE UNIT, SCHOOL OF AGRICULTURE, CAMBRIDGE, ON THE EXCHANGE OF WATER VAPOUR, HEAT AND MOMENTUM NEAR THE GROUND. The expts. were to test the validity of equations connecting rate of evaporation from soil with absolute humidity and temperature at 2 heights and velocity of air at 2 heights (under adiabatic conditions).

188. Penman, H. L. Proc. Royal. Soc. 1948, 193A, 120-145
WATER: NATURAL EVAPORATION. Two theoretical approaches to evaporation from saturated surfaces are outlined, the first being on an aerodynamic basis in which evaporation is regarded as due to turbulent transport of vapour by a process of eddy diffusion, and the second being on an energy basis in which evaporation is regarded as due to turbulent transport of vapour by a process of eddy diffusion, and the second being on an energy basis in which evaporation is regarded as one of the ways of degrading incoming radiation. A combination is suggested that eliminates the parameter measured with most difficulty, namely, surface temperature, and provides an opportunity to make theoretical estimates of evaporations, rates from standard meteorological data. Experimental work to test the theories show that the aerodynamic approach is not adequate and an empirical expression previously obtained is a better description of evaporation from open water. The energy balance is found to be quite successful. Evaporation rates from wet bare soil and from turf with an adequate supply of water are obtained as fractions of that from open water, the fraction for turf showing a seasonal change attributed to the annual cycle of length of daylight.

189. Pieteneva, N. and Rehbinder, P. Acta Physiochim. U. R. S. S., 1947, 22, 1-12
SPHEROIDAL WATER DROPS: EVAPORATION; EFFECT OF SURFACE-ACTIVE SUBSTANCES. The effect of surface-active substances on the evaporation of water drops in the spheroidal state has been investigated. A sharp decrease in the rate of evaporation of drops, $V_o=R/r_o$ (where R is the radius of the drop and r_o the time of complete evaporation) is observed in the vicinity of the temperature, t_s, at which the spheroidal state is reached, and this temperature is found to decrease appreciably.. Aqueous solutions of sodium oleate exhibit characteristic deviations from the invariance of the quantity r_c/R observed for pure water. The possible reasons of these deviations are discussed. Additions of a less volatile organic substance to water—a hydrocarbon oil-produce a shift in the temperature, t_s, at which the spheroidal state sets in, in the direction of higher temperatures, this being due to the increase in the rate of evaporation of drops with increasing concentration of the oil.

190. Powell, R. W. Tr. Inst. of Chem. Engrs. Ldn. 18 (36) 1940
Abstr. B p. 331. 1940
FURTHER EXPERIEMNTS ON THE EVAPORATION OF WATER FROM SATURATED SURFACES. See also Engineering 150 238-278 1940. An account is given of experiments which have been carried out in an open circuit wind tunnel to determine the rate of evaporation of water from various (unheated) geometrical surfaces, including spheres, cylinders set transverse and parallel to the air-stream and planes set at various angles to the direction of the stream. For each

type of surface it is possible to correlate results obtained for a range of surface lengths (or diameters) and air speeds. Attention is directed to the use of ridges for increasing the rate of evaporation from plane and cylindrical surfaces set parallel to the direction of the air stream. Measurements are included of the natural evaporation which occurs when moistened surfaces are exposed in an unventilated chamber.

191. Powell, R. W. Phil Mag. (vii), 1940, 29, 274. Bull. int. Inst. Refrig, 1940, 21, 334

NOTE ON THE DISTRIBUTIONS OF TEMPERATURE AND VAPOUR PRESSURE AROUND A HORIZONTAL WET CYLINDER. Experiments are described in which unventilated thermo-couple psychrometers were used to determine the temperature and vapour pressure distributions above, below and to one side of the wet surface of a horizontal cylinder. The presence of a convection current passing over the surface on a downward direction was revealed when the surface was cooled to a temperature well below atmospheric. When the surface temperature was raised, a point was reached at which little movement of air occurred and, under the conditions of the experiment, this took place when the surface temperature was just over 1°C below that of the surroundings. With further increase in surface temperature the convection currents changed to an upward direction. The rate of evaporation fell to a minimum in the region of little air-movement and, assuming that the whole loss of moisture took place by diffusion, experimental data for vapour pressure gradients near the wet surface led to values of the correct order for magnitude for the coefficient of diffusion of water vapour into air. The bearing of these results on problems of food storage and transport is discussed. In absence of a forced air circulatory system, there will be a tendency for moisture to accumulate near the ceiling of a chamber containing evaporating bodies with surfaces above, or even slightly below, air temperature, and a corresponding tendency for concentration of moisture near the floor, should the evaporating surface be cooled considerably below air temperature. Results also demonstrate the difficulty of predicting the rate of evaporation from a surface in relatively still air.

192. Powell, R. W. Trans. Farad. Soc., 39, 311, 1943

THE INFLUENCE OF SURFACE FILMS OF OIL ON THE EVAPORATION OF WATER. Experts on the effect of oil films on the rate of evaporation of water show that while mono-molecular films cause but little reduction in the rate of evaporation from an underlying water surface, the effect of multi-molecular films may be appreciable. It has been shown that the reduction becomes relatively greater as the air velocity is increased, and that the order of the effect can be estimated from a knowledge of the diffusion coefficients of water vapour through air and oil. This research has a close bearing on the effect of surface films of brick oil or the rate of drying of clay.

193. Rees, W. H. Shirley Inst.Mem.1944,19,No.4

SOME EXPERIMENTS ON THE EVAPORATION OF WATER FROM A PLANE SURFACE. A simple volumetric method was devised for measuring the rate of evaporation of water from a moist surface; observations of the movement of the liquid along a capillary tube provide data for calculating the rate of evaporation. Also the effect of layers of Fabric on the plate. J. Textile Inst. 36 T.165 1945.

194. Richardson, B. Am.Soc.Civil Engrs. - Proc.,vol.56,No.8, Oct.1930,pp.1929-1934

EVAPORATION AS A FUNCTION OF INSOLATION. Discussion by D. P. Krynine, R. C. Wells and N. W. Cummings, of paper indexed from issue of May 1930.

195. Rohwer, C. U.S.Dept.Agr.,Tech.Bull.271(1931)

RATE OF VAPORIZATION IN AIR STREAMS.

$E = (1.465 - 0.0186B)\ (0.44 + 0.118W)\ (E_s - C_a)$ = inches /24 hours.
B = barometer, in. Hg.
e = v.p. in. hg.
W = wind vel - m./hr.

196. Rohwer, Carl J. Agr.Research 46,715-29(1933)

EVAPORATION FROM SALT SOLUTIONS AND FROM OIL-COVERED WATER SURFACES. Evaporation from NaCl solutions of 5% concentration or less does not differ materially from that from water but evaporation from solutions of 10% concentration or more is definitely less. If the vapor pressure is corrected for the effect of the NaCl the computed rates of evaporation agree well with the observed rates, but the agreement is closer for the weaker than for the more concentrated solutions Evaporation from Na_2SO_4 solutions agrees closely with evaporation from water when exposed under similar conditions. Evaporation is reduced by the presence of an oil film, but the rapidity with which the film is dissipated by rainfall, wind and other causes indicates that this method is not economically feasible for reducing evaporation from large water surfaces.

197. Rohwer, C. Amer.Soc.Civil.Engn.59 223-53,1933 Feb.

EVAPORATION FROM DIFFERENT TYPES OF PANS. Recommended use of Class A. land pans of the weather bureau for evaporation studies. Many data are given in support. Results are not expressed as transfer coefficients.

198. Sanderson, Marie Can.Jnl.of Research C.26.445-454 Aug.1948

AN EXPERIMENT TO MEASURE POTENTIAL EVAPO-TRANSPIRATION. A method of obtaining the daily values of the potential evaporating power of the atmosphere. Relations between evaporation from a vegetation covered soil, the run-off, and the climatic conditions.

199. Sharpley, B. F. Boelter, L. M. K. Ind.Eng.Chem.1938 30
1125-1131,

EVAPORATION OF WATER INTO QUIET AIR. FROM A ONE-FOOT DIAMETER SURFACE. Numerous curves and data derived from the evaporation of water in a pan. Rates were measured by an evaporimeter containing an optical wedge producing interference bands. Tabular summary of evaporation results. 11 References.

200. Shepherd, Hadlock and Brewer Ind.Eng.Chem.1938 30,388-97
DRYING MATERIALS ON TRAYS. Data on evaporation from plane surfaces. Methods of calculation for surface temperature.

201. Sklyarenka, S. I. Baranaiev, M. K. J.Phys.Chem.U.S.S.R.18 447.
Meshueva, K. I. 1944 Br.Absts.A.1.45.
Feb.1946

EFFECT OF FILMS OF SURFACE ACTIVE SUBSTANCES ON THE RATE OF EVAPORATION OF WATER FROM AQUEOUS SOLUTIONS 3. Cetyl alcohol reduces evaporation to half. Ethyl phthalate has less effect.

202. Stacey, A. E. Jr. Ind.Eng.Chem.1938 30 12 p.1385-9
EVAPORATION RATES OF MOISTURE FROM A WET MATERIAL AND FROM A FREE WATER SURFACE. Experimental detns. of the rates of drying various materials in a laboratory oven, and comparison of the data obtained. Curves. are given for (a) Drying time, and (b) Rates of evaporation, for Paper Pulp, Lithol Red, Carbon pigment, Stannic chloride and Clay as being materials typical of classes.

203. Swensson, A. Arkir.Mat.Astron.Physik A-22 283,1932
EVAPORATION AND COOLING OR HEATING IN A LAMINAR GAS FLOW OF CONSTANT VELOCITY. Application to Assman's Aspiration Psychrometer. (In German).

204. Thiesenhusen, H. Gesundheits Ing.53,113-9(1930)
VAPORIZATION OF WATER INTO AIR. Effect of air velocity, temperature, humidity, etc.

205. Thomas, - Ferguson, - Phil.Mag.Ldn.Edinburgh and Dublin 34
308-321 1917

ON EVAPORATION FROM A CIRCULAR WATER SURFACE. Grams per sec.
evaporation $= K a^{1.5}$
$a =$ radius surface.
$K =$ coefficient of evaporation 4 Kp, where $K =$ diffusion coefficient of water vapour into the air. $p =$ potential water vapor pressure difference between surface and surrounding air. Mathematical analysis in support. The main point is that M varies as $a^{1.5}$.

206. Tschudin, K. Helvetica Physica Acta 19 No.2 p.91-102 8/4/46

DIE VERDAMPFUNGGESCHWINDIGKEIT VON EIS. (The rate of evaporation of ice) in German. Description of apparatus in which a thin layer of ice is weighed on an electrical balance, while in very close proximity to the condensing surface. At temperatures - 85°C to - 60°C the evaporation coefficient is independent of temperature and is found to be 0.94 as against the theoretical maximum of 1.0. This contrasts with measurements obtained elsewhere, where in the fluid state values of 0.04 were obtained.

207. Tverskaya, N. P. Isv. Akad. Nauk. S. S. S. R. 14(2) 164-170 1950. D. S. I. R. 5958/C. T

THE EFFECT OF A CURRENT OF AIR ON THE RATE OF EVAPORATION OF A DROP OF WATER. Results given of experimental invest. of the numerical values of the expression for the wind factor. Tests were made for Reynolds' numbers from 50 to 500, and the values of the wind factor obtained practically and theoretically were compared.

208. Wade, S. H. Industrial Chemist, 1942, 18, 55-58

LIQUIDS: EVAPORATION IN CURRENTS OF AIR. An equation for covering conditions of both natural and forced convection of liquids is suggested of the form $E = ke_s + e_v = ke_s + b(p_e - p_a)v^n$, where E is the observed rate of evaporation k is a parameter which is a function of the velocity of the impressed draught, v is the air velocity, e_v is the rate of evaporation produced by forced convection, e_s is the rate of evaporation produced by natural convection, p_e is the vapour pressure of the liquid at the temperature of the evaporating surface (mm. of mercury abs.) p_a is the partial vapour pressure of the liquid in the incident air stream, and b and n are constants. Experimental studies of the evaporation of various organic liquids and water from a free surface in a pan in a wind tunnel under definite and reproducible physical conditions of forced and natural convection are described. Graphs are given showing the effects of velocity of air, molecular weight, and vapour pressure on rate of evaporation. Applying these results, the final equation for the rate of evaporation in g. per second of water, acetone, ethyl acetate, benzene, toluene, trichlorethylene, and carbon tetrachloride is $E = 10^{-7} M^{0.71} [9.8 \log^{-1}(-0.01 v)](p_e - p_d)^{1.25} + 1.57 v^{0.85}(p_e - p_d)$

At velocities exceeding 130 cm. per second approximately 95 per cent. of the individual experimental data for all the solvents except benzene satisfy this equation to within ± 10 per cent.

209. Wagner, A. Gerlands Beitrage 34 Kopen Band III 85-101, 1931

ON THE PROBLEM OF EVAPORATION. A mathematical treatment.

210. Wilson, K. Birkbeck College Nature Vol. 164 p. 1013 10 Dec. 1949

TRANSPIRATION INTO A SATURATED ATMOSPHERE. Describes the water conditions inside the leaf necessary to permit the formation of convex droplets (whose vapour pressure will exceed that of a saturated atmosphere)

Quotes D. Thoday - Nature 164 p. 541 1949
Dixon and Borwell - Sci. Proc. Roy. Soc. Dublin 22 211 1940
Sresnevski see Maximov "The Plant in Relation to Water 159 1929
Lewis. Discussion of Faraday Soc. No. 3 159 1948

Diffusion

211. —— Comptes Rendus 15 1167 1842

POISEULLE'S LAW. The gas volume flowing through a capillary tube varies as the 4th power of diameter. See under Leather R. S. Edwards 1932.

212. Arnold, J. H. Trans. Amer. Inst. Chem. Engrs. 40 361-378 1944

STUDIES IN DIFFUSION III. UNSTEADY STATE VAPOURISATION AND ABSORPTION. Mathematical analysis of diffusion in gases. See same author in Ind. Eng. Chem. 22 1091 1930 and in J. Amer. Chem. Soc. 52 3937 1930.

213. Arsdel van, W. B. Chem. Eng. Progress 1, No. 1, Trans. Amer. Inst. Chem. Engrs., 1947, 43, 12-24 (through Chem. Abstr., 1947, 41, 1911)

CUT VEGETABLES: DRYING; APPROXIMATE DIFFUSION CALCULATIONS. Some of the observed complexities of drying-rate curves have been ascribed to a variability of the diffusivity of the substance with changing moisture content. Evaluation of the suggestion has been difficult, because the generalised diffusion equation is not integrable. Approximate numerical procedures are applied by the author to explore the effect of a variable diffusivity in the low-moisture range upon the shape of the rate curve for the infinite slab, the long cylinder, and the sphere. Either vapour pressure or concentration can be used as the driving potential. The effects of changing the thickness of the body and changing the relative importance of the surface mass transfer coefficient are investigated. Typical experimental rate curves, determined during the dehydration of cut vegetables, exhibit curvature of the type predicted by such calculations, and to a degree that might well be expected on the basis of independent measurements of diffusivity in hydrophilic solids. 38 References.

214. Aten, A.H.W. Jr. Dreve, J.W. Trans.Farad.Soc.44 202 Apr.1948
SIMPLE APPARATUS FOR MEASUREMENT OF DIFFUSION RATES.

215. Babbitt, J. D. Canad.J.Res.A, 1941, 19, 42
THE DIFFUSION OF WATER VAPOUR THROUGH A SLIT IN AN IMPERMEABLE MEMBRANE. To prevent condensation of moisture in walls of buildings, a membrane of some material having vapour barrier qualities is usually provided in the wall. Difficulties have been found in evaluating the effects of cracks or joints in such a vapour barrier membrane. An equation has been developed from the elementary equation for diffusion of a vapour, giving the relation between the amount of vapour diffusing through a slit in an impermeable membrane and the width of the slit. Results obtained by means of this equation compared satisfactorily with experimental values.

216. Barrer, R. M. Cambr.Univ.Press 1941 464 P.158 figs.
DIFFUSION IN AND THROUGH SOLIDS.

217. Baxter, S.
DIFFUSION IN SOLIDS. See under Textiles.

218. Bradley, H.
DIFFUSION IN SOLIDS. See under Leather. (1) Moisture in leather. (2) The drying and wetting of leather.

219. Brown, R. C. Proc.Phys.Soc.53 233-4 1941
CAPILLARY TUBE. ENERGY ASSOCIATED WITH RISE. Energy of rise against gravity = viscous energy. From the sum of these equated to the energy of wetting the walls, the usual capillary rise equation is obtained.

22 . Brown, R. C. Proc.Physical Soc., 59, 429, 1947
THE FUNDAMENTAL CONCEPTS CONCERNING SURFACE TENSION AND CAPILLARITY. On the basis of the usual idea of cohesion between molecules it can be shown, for instance, that, in contradiction to what is often contended, it is not necessary to deny the reality of surface tension during the course of an explanation of the common phenomena which were, at one time, regarded as providing evidence of its existence. It is possible, also, to gain a less abstract conception of the distinction between free and total surface energy than that provided by a purely thermodynamical discussion. The customary assumption that in a system containing a solid/liquid interface the surface energy of the solid plays an identical role with that of the liquid is criticised, and the conception of surface energy as the work done during the rupture of a column of material is examined. Capillary elevation is regarded as a consequence of negative surface tension in the liquid at the solid/liquid interface, and the usual expression for the capillary rise is derived from this idea. (12 figs.)

221. Brittin, W. E. J.Appl.Phys., 17, 37, 1946
LIQUID RISE IN A CAPILLARY TUBE. A theory of the dynamics of capillary rise is developed by making certain assumptions as to the nature of the motion of the liquid in the tube. The most important assumptions are that the same forces act on the liquid when it is in an accelerated state of motion as when it is in a steady state, that the surface tension is constant, that the angle of contact between the meniscus of the liquid and the tube wall is constant, and that the wetting of the tube is not a rate-determining factor of the motion. This theory leads to a second-order non-linear differential equation, the solution of which represents the motion of the liquid in the tube. A formal solution of the differential equation is obtained in the form of a double Dirichlet series. Approximations to the series are compared with experimental data, and it is concluded that the agreement between theory and experiment is satisfactory.

222. Burr and Stamm
DIFFUSION IN SOLIDS. See under Timber.

223. Calhoun
DIFFUSION IN SOLIDS. See under Foundry Cores.

224. Carman, P. C. Disc.Farad.Soc.,No.3, 72, 1948
SOME PHYSICAL ASPECTS OF WATER FLOW IN POROUS MEDIA. When flow in a porous medium is controlled by viscosity only, it obeys the Kozeny-Carman law with remarkable accuracy, and it is pointed out that the only rational pore diameter calculable from permeability measurements is d_2=4x (hydraulic radius) (m). Certain conditions must be fulfilled for permeability measurements to have significance for calculation of pore diameters or specific surface, and these are discussed in some detail. As the permeability method for specific surface is well established, attention is merely directed to its extension to give both density and diameter of cellulose fibres in paper pulps. Pore diameters as normally calculated by the bubble pressure method are equal to 4x (hydraulic radius) and should therefore equal d_2 calculated from permeability. The method, however, is open to considerable uncertainty and error.

225. Comings, E. W. Ind.Eng.Chem. 26 1096-1098, 1934
Sherwood, T. K.
MOISTURE MOVEMENTS BY CAPILLARITY IN DRYING GRANULAR SOLIDS. The mechanism of movement is illustrated diagramatically and the capillary forces involved are described. Data are given for a plastic clay mix. 10 references.

226. Deag. Bell Laboratory Records 1947 25 227-30
DIFFUSION THROUGH PLASTIC FILMS

227. Gilliland, E. R. Ind.Eng.Chem.26 681 1934
DIFFUSION COEFFICIENTS IN GASEOUS SYSTEMS.

228. Gilliland, E. R. and Sherwood, T. K. Ind.Eng.Chem.,25 1134-6(1933)
THE DRYING OF SOLIDS VI, DIFFUSION EQUATIONS FOR THE PERIOD OF CONSTANT DRYING RATE.

229. Hackett, F. E. Trans.Faraday Soc.,17,260,(1921)
RATE OF ASCENT OF LIQUIDS THROUGH GRANULAR MEDIA.

230. Hey Phil.Mag.22 492 1936
DIFFUSION IN ZOOLITIC SOLIDS.

231. Held, van der E. F. Chem.Abstr.38 1159 1944 Gesundh-Ing. 1941,64,211-6
DIFFUSION PHENOMENA IN ASSOCIATION WITH THE DRYING OF MATERIALS. Theory of diffusion and its parallelism with the theory of heat transfer, when evaporation or precipitation takes place on one side of the heating surface. Application to surface drying. A diffusion coefficient has been found applicable to the internal drying of porous substances, by multiplying the coefficient applicable to normal circumstances by the pore surface per m^3 and dividing by the mean length of the canals between 2 surfaces 1 m. apart. (From Feuerungstech, 1942, 30, 20).

232. Henry, P. S. H. Proc.Roy.Soc.A.171,215-241,1939
DIFFUSION IN ABSORBING MEDIA. Two processes, the diffusion of moisture through the porous solid and the diffusion of the heat of absorption. Equations for each are derived. Materials of different pore characteristics, and varying external conditions, are treated in conjunction with the above, with special reference to moisture movement in cotton.

233. Hodgins, J. W. et al Can.J.Res.1946 24B 167-77
FLOW OF GASES THROUGH VERY FINE POROUS MEDIA. PERMANENT GAS FLOW. KNUDSON & POISELLE EQUATIONS. Condensable gases deviate considerably from these.

234. Horton, C. W. and Rogers, F. T. J.Appl.Phys.,16,367,1945
CONVECTION CURRENTS IN A POROUS MEDIUM. The problem is considered of the convection of a fluid through a permeable medium as the result of a vertical temperature-gradient, the medium being in the shape of a flat layer bounded above and below by perfectly conducting media.

235. Hougen, O.A. McCauley, H.J. Trans. Amer. Inst. Chem. Engrs. 36
Marshall, W.R. 183-209 1940

LIMITATION OF DIFFUSION EQUATIONS IN DRYING. In the drying of solids the movement of water by diffusion is restricted to the equilibrium moisture content below the point of atmospheric saturation, and to single-phase solid systems in which the water and solid are mutually soluble. The first category applies to the last stages in the drying of clays. Differential diffusion equations can be applied to calculate moisture distribution and rates of drying, under the conditions cited, but integrations should allow for the variable nature of diffusibility. It has been found that diffusivity decreases with decreasing moisture content or temperature, and with increasing pressure or density. Interstitial water is subject to movement by gravity and capillarity. Water flow in drying due to capillarity applies to water not held in solution, and, in the case of clays, to all water above the equilibrium moisture content at atmospheric saturation. Water vapour may be removed by vapour diffusion through the solid provided a temperature gradient is established, by heating. This process may be applied to any solid where heating takes place at one surface and drying from the other, and also where water is isolated between granules of solids.

236. Kaye and Laby Phys. & Chem. Constants

DIFFUSION CONSTANT FOR WATER VAPOUR IN AIR. $D = 0.248$ at 18°C = mass in grams of water vapour which passes in one second through 1 sq. cm under unit concentration in grams/c.c./ cm. This constant is approximately proportional to the square of the absolute temperature. At 23°C, 25°C and 33°C, $D = 0.2566, 0.2601, 0.2743$ respectively.

237. Kotscher, O. and Forsch. IngWes., 1940, 11B, Forschungsh.
Rohnalter, H. Nr. 402. Chem. Abstr., 1941, 35, 6487

HEAT-TRANSFER AND VAPOUR-DIFFUSION IN MOIST MATERIALS. (transl. title). Shows that the Stefan diffusion law is applicable to diffusion of heat and vapour through moist Materials. Experimental work demonstrated the relation between heat-conductivity, water content, porosity, temperature and temperature drop within any material. At a temperature of 60°C, the heat-conductivity of a porous material was found to be independent of its moisture content.

238. Krischer, O Z. Ver. Deut. Ing. 82 373, 1938

FUNDAMENTAL LAW OF MOVEMENT OF MOISTURE IN DRY MATERIALS.

239. Lederer, E. L. Seifensieder Ztg 51 774-9, 1924

CALCULATIONS FOR THE DRYING OF SOAPS. See under Soap.

240. Le Grand, E.J., Rense, W.A. J.Appl.Phys., 16, 843, 1945.
DATA ON RATE OF CAPILLARY RISE. General aspects of the dynamics of capillary rise are considered with reference to extant theories. A stroboscopic method used to study the rise of a liquid in a capillary tube is discussed. Tables are presented showing the observed heights at various times during the rise for the liquids - water, ethyl alcohol, and glycol in each of three capillaries of different diameters.

241. Levi, D. L. Trans.Farad.Soc., 42A 152-5 1946.
COMPARISON OF ENTROPY AND ENERGY CHANGES IN DIFFUSION AND DIELECTRIC RELAXATION PROCESSES. Values of D.E. and D.S. for the diffusion of water vapour through various solids are recorded and interpreted. Positive values of D.S. are attributed to lattice disordering (hole formation), negative values to the requirement of a particular mol. orientation. The same interpretation can be applied to values of D.E. and D.S. for dielectric relaxation.

242. Levi, D. L., Thomas, A. M. Br.Electr. and Allied Ind.Res.Asscn. Tech.Rept.A/T 103. 17pp.1948.
MOISTURE PERMEABILITY, DIFFUSION AND SORPTION IN ORGANIC FILMS. 1. Experimental Investigation. Apparatus and results of tests on films of various polymers, linseed oil and varnish films. Constants are derived for the three phenomena investigated and numerous tables and curves are given. This is a continuation of the work in report A/T.92. Proe. Phys. Soc. 57 324. 1945.

243. Luikov, A. V. Izvestiya Teplotekh.Inst.1933, No.3, 20-34.
INVESTIGATION OF THE DYNAMICS OF DRYING. Equation for the diffusion of humidity during the process of drying of solids. Polemical with T. K. Sherwood, D. D. Kiley and G. E. Mangsen (C A. 26, 786, 2255); A. B. Newman (C.A. 26, 786, 1362). A. A. Boehtlingk.

244. Luikov, A. V. Trans.Thermo-Techn.Inst.Moscow 1933 No.7, 49-52.
EQUATIONS OF THE DIFFUSION OF WATER IN THE DRYING PROCESS. A Math. Analysis.

245. Mc.Creight and also Zeukovitch, F. A.
DIFFUSION IN SOLIDS. See under Ceramics.

246. Mc Dermott, P. F. Refrig.Engr. 42 1 103-111. Aug.1941.
MOISTURE MIGRATION. A survey of existing knowledge. Directed to understanding the migration of moisture in building structures and humid storages. Mc Dermott classifies:- 1. Movement of total volumes (water vapour.) 2. Diffusion. (Movement of one gas through another. This is dependent upon molecular energy.) 3. Movement by hygroscopic action. (All phenomena of intimate association of moisture with solids.) Hygr. phenomena are associated with properties

of solids, whereas 1 and 2 occur in absence of solids (except for large holes) (a) absorbed water in pores. (b) absorbed water on surfaces. The above are studied for their combined effect on movement through walls, etc. 42 Refs.

247. McKay, A. T. Proc.Phys.Soc.42,235,1930.Trans.Farad.Soc.28 136. 1932.
DIFFUSION EQUATIONS SOLVED SUBJECT TO CERTAIN ASSUMPTIONS.

248. McKay, A. T. Proc.Phys.Soc.(London) 44,17-24 (1932).
DIFFUSION FOR THE INFINITE PLANE SHEET.

249. Ceaglske, N.H., Hougen, O.A. Ind.Eng.Chem.29. 805-813 July 1937.
DRYING GRANULAR SOLIDS. Describes experimental work tending to prove that the drying rate of granular substances is determined not by diffusion but by capillary attraction.

250. Newman, A. B. Chem.and Met.Eng.,vol.38,No.12,Dec.1931, pp.710-713,2 figs.
APPLYING DIFFUSION CALCULATIONS TO DRYING POROUS SOLIDS. Discussion of theory developed by Sherwood concerning drying of porous solids by evaporation of liquid from surfaces of solids, using air currents to effect evaporation; in theory developed, three possible distinct stages in drying process are shown.

251. Newman, A. B. Trans.Amer.Inst.Chem.Engrs.1931.27, 203-216. 310-335.
THE DRYING OF POROUS SOLIDS - DIFFUSION CALCULATIONS AND SURFACE EMISSION EQUATIONS. Relations for diffusion in shapes other than slabs.

252. Osburn and Katz Trans.Amer.Inst.Chem.Engrs.70 243-5 - 1944.
STRUCTURE AS A VARIABLE IN THE APPLICATION OF THE DIFFUSION THEORY.

253. Peek Phys.Rev.35,1930.
DRYING - DIFFUSION.

254. Rense, W. A. J.Appl.Phys.,15,436,1944).
RATE OF RISE OF WATER IN CAPILLARY TUBES. An equation for the rate of rise of a liquid in a capillary tube is developed, assuming that the rise is turbulent. The equation is: $Z = \text{constant} + \left(\frac{1}{k^2}\right) \log t$

where Z is the height of the meniscus above the general level, k^2 is a constant and t is the time. The rise of water in a capillary tube of radius 0.0316 cm. was photographed several times in stroboscopic light of interval 1/20 sec. Measurements were taken of the height at each interval of time, and the curve obtained by plotting these results was found to be best represented by the equation $Z = 4.65 + 1.04 \log t$. It is suggested that the method could be applied as a dynamic method for finding Reynolds' number.

255. Richards, L. A. J.Agr.Research 37,719(1928).
CAPILLARY POTENTIAL. Explains concept and gives explanation of apparatus for measuring - also data on relation between cap. pot. and % H_2O. 20 Refs.

256. Rideal, E. K. Phil.Mag.44,1152,(1922).
FLOW OF LIQUIDS UNDER CAPILLARY PRESSURE. Capillary movement of liquids through horizontal tubes.

$$x^2 - \frac{l\ r\ t}{2u} \quad x = \text{distance} \quad l = \text{surface tension} \quad t = \text{time} \quad u = \text{viscosity}$$

Data on several liquids check formula.

257. Rose, H. E. Proc.Inst.Mech.Engrs.1945 153. War Emergency Issue No.5 141-161.
FLOW OF GASES AND LIQUIDS THROUGH POROUS MEDIA. Reynolds number plot. His own data and those of previous investigators correlated by a friction factor.

258. Rouse, Jr. P. E. J.Amer.Chem.Soc.,1947,69,1068-1073.
FILMS: VAPOUR DIFFUSION IN -. A method is given for calculating the diffusion coefficient of a vapour within a film as a function of concentration. Data required are the permeation rates under several vapour pressure differences and the sorption isotherm. The method also furnishes a means for constructing the gradients of the effective vapour pressure and of the concentration of the vapour within the film through which vapour is passing at a steady state. Data are presented for water permeation and water sorption of the polythene and nylon, and the diffusion coefficients of water vapour in these films at 25°C. are obtained as functions of concentration. Curves representing the vapour pressure and concentration gradients are also presented.

259. Sherwood, T. K. Ind.Eng.Chem.21 12-15. 976-80. 1929.
THE DRYING OF SOLIDS. I AND II. Constant rate for a surface adjacent to a large dry edge was 70% greater than for a negligible dry edge. Curves. Equations. Applicable to clay, soap, slab, wood. Drying by internal diffusion Heat conduction equations. Moisture Gradients For soap - Diffusion Constant varies with moisture content.

260. Sherwood, T. K. Trans. Amer. Inst. Chem. Engrs. 1931, 27, 190.
THE DIFFUSION OF MOISTURE IN SOLIDS. Applications of theoretical diffusion equations.

261. Sherwood, T. K. Ind. Eng. Chem. 24, 307-310, 1932.
THE DRYING OF SOLIDS. IV. Applications of the Diffusion Equations.
For Slab - Parabolic function of distance from surface.
Application of Diffusion equations to drying rates of clay slabs.

262. Sherwood and Gilliland Ind. and Eng. Chem. 25, 1134-5. 1933.
DRYING OF SOLIDS. VI. Diffusion equations for the period of constant drying rate in a solid clayware stock. Treatment of moisture distribution. Equations. These are found to be useful in calculating the length of the constant rate period and critical moisture content, and supply an important link.

263. Sherwood, T.K., Gilliland, E.R. Ind. Eng. Chem. 26, 1093-6. Oct. 1934.
DIFFUSION OF VAPOURS THROUGH GAS FILMS. The results of experiments on the rates of vaporisation of various liquids into air are reviewed and rules are given for estimating the diffusion rate of a vapour through a gas film on the basis of data on the diffusion rate for another vapour. Numerical examples illustrate the necessary calculations.

264. Straub, J., van Eijk, M., de Wilde, J.H., Hekker, Th. Rec. Trav. Chim., 1946, 65, 545-548.
MEMBRANES: STEADY STATE IN DIFFUSION PROCESSES; TEORELL EQUATIONS. Equations governing Straub's earlier experimental examples of equilibrium (steady state) in constant diffusion processes through membranes were given by Teorell (1935). Straub's experiments have been extended by studying the case of the constant diffusion of an electrolyte (called "active") from the inside to the outside of a permeable tube, when concentrations inside and outside are kept constant, and the influence of this constant diffusion on the distribution of other electrolytes (called "passive") inside and outside. Picric acid was used as the active electrolyte and suitable passive electrolytes in different experiments were hydrochloric, hydrobromic and chloric acids at various concentrations. The results are presented in a table and compare satisfactorily with numbers calculated on the basis of the Teorell equations.

265. Thomas, A. M., Gent, W. L. Br. Elect. & Allied Inds. Res. Assn., Tech. Rept. A/T. 92. 1944. 19pp. Proc. Phys. Soc. 57 324, 1945.
PERMEATION AND SORPTION OF WATER VAPOUR IN VARNISH FILMS. Investigation on Varnish and Polystyrene Films. The effect of structure on diffusion is discussed, and the relations of the results to the problems of electrical insulation are considered. Bibliography. Further work in Tech. Rept. A/T. 103.

266. Vassiliou and White Trans.Br.Ceram.Socy.1948 47,9. 3[illegible]1-[illegible]. Sept.
VAPOUR PRESSURE - CAPILLARITY RELATIONSHIPS IN CLAYS AND APPLICATION TO CERTAIN ASPECTS OF DRYING. Temperature gradient and movement of water along tubes and capillaries. 28pp. 17 curves illustrating water movement. Work indicates that moisture moves through clay by an evaporation condensation procedure. Applicable to the later stages of clay drying and to the tray drying of most granular materials.

267. Yoshida, Y. Kumamoto Technical College, 1934, 7pp. figs. tables.
SIMPLE FORMULA FOR ESTIMATING HEIGHT OF CAPILLARY RISE IN GRANULAR DEPOSIT.

Permeability

268. Adam, N K. Disc.Farad.Soc.,No.3,5,1948.
PRINCIPLES OF PENETRATION OF LIQUIDS INTO SOLIDS. Unless the contact angle of a liquid in a capillary of small radius is exactly 90^0, a curved meniscus will result; the contact angle varies, however, being a maximum when the liquid advances over a dry surface. A greater pressure is required to expel a liquid from a capillary than to drive it in, and the difference between advancing and receding contact angles can be large, up to 60^0 on smooth surfaces, and larger values for rough surfaces; the hysteresis appears to be larger for water than for organic liquids. For "receding" angles the minimum contact angle of zero is not uncommon, although less so with "advancing" angles. The maximum advancing angle on a smooth surface is probably between 110^0 and 120^0 and it seems unlikely that with organic substances contact angles greater than 120^0 can exist. Greater apparent contact angles can be obtained with rough surfaces and generally roughness increases the differences between the real contact angle and 90^0. In regard to penetration into capillaries of complex shape, penetration pressure will decrease, even to become negative, when the meniscus has to find its way past a constriction in a pore; the constriction need not be sharp, the effect depending on the slopes of the walls. On the question of the mechanism of penetration only qualitative consideration is given, such as when the smallness of the bore allows attraction of the walls to extend across them; liquid in the pores will everywhere be within range of the attraction.

268a. van den Akker, J. A. Paper Trade J.,1947,124, TAPPI, 269-274.
FILMS: WATER VAPOUR PERMEABILITY; DETERMINATION BY MEANS OF ELECTRIC HYGROMETER. The development of special electric hygrometers having very small moisture absorption capacities has made possible the measurement of a small water vapour permeability at low temperature. The special hygrometer and associated circuit are described. Three hygrometric methods employing this hygrometer for

the low-temperature determination of water vapour permeability are described and discussed. These are the dynamic method, the comparison method, and the sweep-gas method. The most sensitive and rapid in use is the dynamic method, which is recommended for industrial control purposes and appears to be suitable for the testing of sheets (such as resins and waxes) of a non-hygroscopic nature. The comparison and sweep-gas methods are steady-state processes, and require the establishment of equilibrium; they are, accordingly, more time-consuming than the dynamic method but yield results that are theoretically free from errors resulting from sorption phenomena. Sources of error are discussed and a few precautions are suggested. See also 126 (1) T. S. p.6. 1948.

269. Babbitt, J. D. Canad. J. Res. A, 1940, 18, 105.
OBSERVATIONS ON THE PERMEABILITY OF HYGROSCOPIC MATERIALS TO WATER VAPOUR. I. OBSERVATIONS AT RELATIVE HUMIDITIES LESS THAN 75%. For transpiration of moisture through hygroscopic materials 2 distinct regions of relative humidity can be distinguished: (1) a region below some value between 70 and 80%, where the moisture movement is proportional to the vapour pressure difference, and (2) a region of high relative humidity, where the moisture movement is not directly proportional to the vapour pressure. A theory is advanced that these 2 regions correspond to the 2 conditions in which water may be present in a hygroscopic material. Fick's law and the form in which it might be expected to apply in the 2 cases are discussed. Measurements for fibreboards showed that below 75% relative humidity the resistance of the board to moisture transpiration is proportional to the thickness. Moisture content gradients through fibreboard samples were determined. Diffusance through a board in which the moisture content gradient is opposed to the vapour pressure gradient showed that the latter is the important factor, and determination of the moisture content gradient indicated that at these low humidities Fick's law is applicable.

270. Barrer, R. M. Discuss. Farad. Soc. 3 61-72 1948.
B.I.424 June 1949.
FLUID FLOW IN POROUS MEDIA. Mathematical discussion. Molecular mechanism of fluid flow has been considered for high pressure in oxide tubes until the pore radius is so small that surface forces predominate.

271. Brabender, G. J. U.S.Pat., 2,400,481, 1946, via R.A. Brit. Rubber Mnfrs. Summ. Curr. Lit., 1946, 24, 369. July, 1946.
APPARATUS FOR TESTING WATER-VAPOUR PERMEABILITY. Apparatus for simultaneously testing water-vapour permeability of two test specimens of a sheet material comprises a thin, light-weight tube having open ends of a size and shape to accommodate an analytical balance and having a small ratio of gross weight to area of test specimens, each end being provided with an outwardly extending

flange, constituting a ledge for receiving a specimen of the sheet material to be tested with a filling of desiccant therebetween, the volume of the tube being small in comparison to the total area of the test specimens.

272. Carman, P. C. J.Agr.Sci.29 262. 1939.
PERMEABILITY OF SATURATED SANDS, SOILS AND CLAYS. This can be calculated with considerable accuracy if the porosity and specific surface are known. The Kozeny theory gives a useful relationship between permeability and porosity, but clays do not conform to the theory in its simple form. The theory can be modified to give a satisfactory representation. From the modified theory it is deduced that clays may have a zero permeability at considerable porosity.

273. Carson, F. T. Paper Tr.Jnl.125(19).118.1947
Packaging Abstr.(130).1948.
THE GRAVIMETRIC (WEIGHED CELL) METHOD OF DETERMINING WATER VAPOUR PERMEABILITY. The technique of the method is described, and the method of wax sealing is included.

274. Cartwright Ind.Eng.Chem.Anal.Ed,19(6) 393 June,1947.
Various types of instruments used, in general, to measure gas permeability of sheet materials, and a new instrument of improved sensitivity.

275. Cheerpow, F. H. Paper Trade J.,1947,125,110,via
Packaging Abs.,1948,5,35.January,1948.
FLOW METHOD FOR DETERMINING WATER VAPOUR PERMEABILITY AT 0°F.
An adaption of the isostatic method for determining gas permeability is used to measure water vapour permeability at 0°F. Air, saturated with water vapour at 0°F., is passed at a known rate over one side of a series of test sheets held in a diffusion cell maintained at 0°F. Air, dried to essentially 0 per cent. R.H. at 0°F., is passed over the other side. The water vapour in each effluent air stream is continuously absorbed in desiccant and the amount determined gravimetrically. Permeability is measured by the rate of gain of water vapour in the dry air. Comparison of total water vapour in both air streams on exit from the cell with theoretical amount entering the cell serves as a check on the accuracy of the determination.

276. Childs, E.C., Collis-George, N. Proc.Roy.Soc.201(1066).392-404.
THE PERMEABILITY OF POROUS MATERIALS. Shews the failure of the Kozeny type of expression based on particle size or specific surface for solids differing from saturated sands. The failure may be avoided by relating permeability to pore size distribution, which may be measured by simpler means than particle size distribution. Arrived at by plotting moisture content against pressure deficiency and interpreting. Experimental determinations of permeability of unsaturated materials are presented, using sand and slate dust, and

results compared with computed values. Agreement better than Kozeny formula. Coeff. of diffusion as a function of the moisture content. Flow of water in a long column is measured and electrical estimation of moisture content.

277. Edwards, R. S. J.I.S.L.T.C. 1.14 392,1930.
2.16 439,1932.

1. Air Permeability. 2. Water Vapour Transmission. See under Leather.

278. Fancher, G.H., Lewis, J.A. Advance Paper,Am.Chem.Soc.Petroleum Div.Meeting,Washington(1933)March.

FLOW OF SIMPLE FLUIDS THROUGH POROUS MATERIALS. By means of an ingenious arrangement, the pressure drop through consolidated and unconsolidated sand cores was measured. Oil, water and air were the fluids used. In the viscous region the pressure drop through unconsolidated sand of 31-39% voids is twice the value given in our Report B-197-19. The authors also report data on lead shot of 34.5% voids; for this the line is 30% lower than the line of B-197-19.

279. Ginsborg, B.L., Poulter, A.C. PATRA.Oct.1948.Packaging Res. Rept.No.2.69pp.

PERMEABILITY TO WATER VAPOUR OF SHEET MATERIALS. The PATRA tentative standard method. 16 Refs.

280. Grover, D.W. Br.Food Mnfrs.Res.Assn Res.Rept.No.2. 31pp.March 1947.

THE STOVING OF CONFECTIONERY. MOISTURE PERMEABILITY OF GELATINE JELLIES.

281. Hauser, P.M., McLaren, A.D. Ind.Eng.Chem.40 112 1948.

WATER VAPOUR TRANSMISSION BY REGENERATED CELLULOSE.

282. Hoxton Phys.Review.1919 13 438.

Extensive expts. on passage of gas through porous material have been carried out by Hoxton. Summary of previous work.

283. Kanagy, J R., Vickers, R.A. J.Amer.Leath.Chem.Assn.45 211-42.1950. Chem.Abstr.44 8145.1950.

FACTORS AFFECTING THE WATER VAPOUR PERMEABILITY OF LEATHER. Data are presented, derived from the A.L.C.A. method of measuring permeability for various types of leather. Above 20% R H., permeability shewed a marked increase, indicating that pure gaseous diffusion was not the complete mechanism of transfer.

284. Ketchum, Westman, Harsh Univ.Ill.Engn.Expt.Stn.Circ.14.(before 1927).

PERMEABILITY OF CERAMIC BODIES.

285. Madgwick, E. Phil-Mag. 13 632(1932).
CAPPILARITY PENETRATION OF WATER INTO POROUS BUILDING MATERIALS.
Fairly simple treatment of capillary forces and integration to relation between distance and time. - time varies as x^2.

286. Newns, A. C. Jnl. Text. Inst. 41(8) T269-T308 Aug. 1950.
THE METHODS OF DETERMINING THE WATER VAPOUR PERMEABILITY OF LAMINAE.
A Review of the Literature. 164 Refs. and Description of Methods.

287. Nissan, A. H. Nature, 157, 267, 1946.
FLOW OF WATER THROUGH VERY NARROW CHANNELS. In these experiments dry air was passed through highly impervious limestone and sandstone cylindrical specimens, and the necessary measurements of pressure, rates, temperatures, etc., taken. It was found that flow of air under such conditions exhibited certain anomalies which led to the belief that there is a sub-viscous regime of flow. The anomalies are, briefly: (a) The rate of flow (corrected for viscosity) is not linear with pressure, but at low rates follows a curve; (b) When the rate is increased, a straight line is obtained for the curve relating the rate of flow to the pressure, but this straight line does not pass through the origin upon extrapolating backward: (c) The permeability of a sample calculated from the flow of air was not constant but varied in a complex manner with the rate of flow. This is, of course, a corollary of (a) above. To summarise: flow appears to follow two mechanisms: (i) ordinary hydrodynamic flow in surface-free systems; (ii) sub-viscous regime flow where the molecules adsorbed at the surface exchange places under distinctly different laws from those observed in non-boundary conditions. In very narrow channels the second form of flow becomes a significant portion of the total flow.

288. Paine, F. A. PATRA. April, 1947. Packaging Res. Rept.
No. 1. 33pp.
THE PERMEABILITY OF ORGANIC MEMBRANES TO GASES AND VAPOURS.
Review of Literature. 59 refs.

289. Renner, M. S. Paper Trade J., 1947, 125, TAPPI, 65-68.
PLIOFILM SHEET: WATER VAPOUR PERMEABILITY DETERMINATIONS; SOURCES OF VARIABILITY. An experiment was conducted to try to identify the sources of variability in the measurement of water vapour permeability at high temperature and high humidity. The experiment was designed to permit an examination of the data by variance analysis. A pliofilm substitute was used in the experiments. Sources of variability studied were the days on which the weighings were made, positions on each of the three shelves in the cabinet, shelves, and the various interactions. The major part of the variability was assignable to the days, although positions, shelves, and the interaction between positions and shelves made significant contributions to the total variability. The low value of the triple interaction,

which included the error of the experiment, indicated the relative unimportance of other variables and the relative uniformity of the film used in the test.

290. Roebuck — Proc. Amer. Acad. 60 537, 1925.
64 287, 1929.
Experimental work on passage of gas through porous materials.

291. Rowley, F. B. — Trans. Amer. Soc. Heat. Vent. Engrs, 1939, 45, 545. Ice & Refrig., 1939, 97, 78 (Abstr.).
A THEORY COVERING THE TRANSFER OF VAPOUR THROUGH MATERIALS. Reports that in many cases the flow of vapour through a material is proportional to the fall in vapour pressure along the path of flow. Accumulation of vapour at any point within a wall is due usually to the fact that the vapour travels more quickly through the warm section of the wall to the accumulation area than from this area to the cold side of the wall. The rate at which vapour travels may be reduced by lowering the relative humidity or by introducing some material with high vapour resistance on the warm surface of the wall.

292. Thomas, A. M. — Br. Electr. & Allied Trades. Research Asscn. Techn. Reports.
MOISTURE PERMEABILITY, DIFFUSION AND SORPTION IN ORGANIC FILMS. Part I. Ref. A/T 103. Part II. Ref. A/T 117. I. Experimental Determinations on films prepared from polyvinyl chloride, polymethyl methacrylate (perspex) insulating varnishes, baked linseed oil and cellulose acetate. II. Analysis of above data by application of thermodynamic and adsorption theories.

293. Van der Akker, J. A. — Paper Tr. J, 1/1948 126. (1) 32-7.
Instrument for water vapour PERMEABILITY of substances at low temperature. Diagrams. The instrument embodies Lithium Chloride in P.V. Acetate.

294. Wink, W. A., Dearth, L. R. — T.A.P.P.I. 32 232-8. 1949. Chem. Abstr. 43 5948. 10/8/49.
MEASUREMENT OF WATER VAPOUR PERMEABILITY AT LOW TEMPERATURE - THE HYGROMETRIC SWEEP GAS METHOD. Depends on the use of a small electric hygrometer which is very sensitive and therefore rapid. (no details). Data are given for permeability of Cellophane. Cellophane kraft laminate. Glassine Laminate. Pliofilm. Sulphite laminate.

295. Zankowitch, F. A.
PERMEABILITY. See under Ceramics.

Thermal Conductivity

296. ----
THERMAL CONDUCTIVITY. See under Textiles:- Speakman and Chamberlain, Baxter, King, Cassie and Baxter, Daniels, Baxter and Cassie.

297. Billington, N. S., Bdg.Res.Stn. Jnl.of Sci.Instr.26(1)p.20-23. 1/9/1949.
THE THERMAL DIFFUSIVITY OF SOME POOR CONDUCTORS. Diffusivity in the ratio Thermal Conductivity/Volumetric Specific. Heat Table giving density, thermal conductivity, specific heat, and diffusivity for building materials (minerals, wood, fibre and cork board, slag wool).

298. Devienne, Marcel J.des Recherches du Centre National de la Recherche Scientifique. Laboratoires de Bellevue No.8 pp.238-245 1949.
THE INFLUENCE OF HUMIDITY ON THE THERMAL CONDUCTION OF GRANULAR SOLIDS. Results of experiments on the influence of moisture on thermal conduction. Tables. Mathematical Treatment. Conclusions:- Experimental evidence indicates that even a small quantity of water, less than 3 grams per litre of the solid, augments the coefficient of thermal conduction by 50%.

299. Edwards, R. S., Brown G.
THERMAL CONDUCTIVITY. See under Leather.

300. Jesperson, H. B. Warme 14 (3) 41-72. 1949.
THE DETERMINATION OF COEFFICIENTS OF CONDUCTIVITY FOR BUILDING AND INSULATING MATERIALS WITH VARYING HUMIDITY. B.R.S. Litr. Comm. No. 362. DSIR/3973/CT.

301. Shannon, W.L., Wells, W.A. Proc.Amer.Soc.Test.Mater.,47,1044,1947.
TESTS FOR THERMAL DIFFUSIVITY OF GRANULAR MATERIALS. This paper presents the procedures, analyses and results of tests to determine, using a simplified test procedure, the thermal diffusivity of several granular materials of types frequently used for base-course construction of highways and airports. Determinations were made with the materials in the frozen and unfrozen condition at several different unit weights and water contents. From the test data obtained, the volumetric heat capacity and the thermal conductivity for each thermal diffusivity determination were computed. The method, where used to determine the thermal conductivity, is relatively simple and inexpensive in comparison with the more precise methods generally used, yet results of tests on one material using the simplified method and a precise method compare favourably. (7 figs., 3 tables.)

TECHNOLOGICAL RES

302. Waddams, A. L. Chem. Inds. 63 206, 1944.
FLOW OF HEAT THROUGH GRANULAR MATERIALS. Review (critical) of past work. Available methods for the study of heat transmission are described.

Heat Transfer

303. Various Authors Ind. Eng. Chem. 30 1938.
HEAT EXCHANGERS AND HEAT TRANSFER. 8 papers on the above subjects.

304. Various Authors. Ind. & Eng. Chem. 40(6) 1019-1113. 1948.
A SYMPOSIUM ON HEAT TRANSFER 15 PAPERS.

305. Ackermann, G. Forschung auf dem Gebiete des Ingenieurwesens - Ausgabe A v 5 n 2 March/April 1934, p. 95-100.
EVAPORATION. Das Lewissche Gesetz fuer das Zusammenwirken von Waermeuebergang und Verdunstung,

306. Arthur, J.R., Linnett, J.W. J. Chem. Soc., p. 416, March, 1947.
THE INTERCHANGE OF HEAT BETWEEN A GAS STREAM AND SOLID GRANULES. PART I. The temperature distribution in a bed of charcoal granules through which air is streaming and to which heat is being supplied by a heater embedded in the charcoal has been studied. The plot of the logarithm of the temperature at the steady state against the distance down the column gives two straight lines, one for the region on the near side of the heater and the second for the region on the far side. The slope of the log T-x graph is dependent on the flow rate but independent of the rate at which heat is supplied by the heater. A mathematical treatment is described which accounts precisely for the results obtained. According to this treatment the rate of interchange of heat between the gas and the solid is proportional to the temperature difference between them. Moreover, the rate of interchange of heat is rapid compared with the conduction of heat through the charcoal, so it is concluded that, at the steady state, the temperature of the air follows closely the charcoal temperature at all points in the system examined.

307. Badger, W. L. Chemical Calalog Co. 1926.
HEAT TRANSFER AND EVAPORATION.

308. Beiler, S.Ya., Rehbinder, P.A., Goldenberg, N.L. Bull. acad. sci. U.R.S.S., Classe sci. tech. 1946. 1491-1495 (through Chem. Abstr. 1947, 41, 2626^{b}).
WATER VAPOUR: CONDENSATION ON HYDROPHOBISED COOLING SURFACES. It is shown that substitution of drop condensation for the usual film condensation of water vapour through adsorptive hydrophobisation of the metallic cooling surface in steam turbines may substantially improve the exchange of heat. Effective and stable hydrophobisation can be obtained with chemisorbed substances of the type of flotation

collectors. The apparatus in which experiments were made is described. Observations consisted in determining the contact angle. by projecting the profile of the drop, the degree of hydrophobisation expressed by $Z = 1 \cos$, with $Z = 2$ corresponding to the limit of hydrophobisation. Before the experiments, the metal surface had been degreased. Emulsions of spindle oil and napthalene soap, and mercaptobenzothiazole proved to be the best hydrophobising agents, as measured by the duration of the persistance of the effect. The transition from film to drop condensation is gradual, there being an intermediate stage of mixed-type of condensation before outright hydrophobisation is established. The effect of concentration is illustrated with potassium isobutylxanthate and 0.1 per cent. is shown to be optimum. On brass, spontaneous emulsions of mineral oils with acid soaps gave effects lasting 100 hours.

309. Brinn, M. S., Friedman, S. J., Industr.Engng.Chem.,40,1050,1948.
Gluckert, F. A., Pigford, R. L.
HEAT TRANSFER TO GRANULAR MATERIALS. Practically no design information is available in the published literature relating to equipment for transferring heat to or from granular materials. One method of performing this operation consists of passing the granular material, as a settled bed, downward through vertical jacketed tubes. Effective thermal conductivities, as calculated from heat transfer data for beds of granular materials moving downward through vertical steam-jacketed tubes, assuming rodlike flow, agreed closely with the conductivities measured in separate experiments with stationary beds. This close agreement indicated that the beds moved substantially as rods. Rod-like flow was visually observed for Ottawa sand by the use of a split-tube technique. Theoretical equations have been developed and design charts prepared for the general case of counter-current heat transfer to a material in rod-like flow in a tube. Equations have also been developed for the case of parallel flow. (18 figs., 6 tables.)

310. Brown, G., Gregory, H. S. B.S.R.A.Rep.No.43. May 1950.
HEAT TRANSMISSION BY CONDENSATION OF STEAM ON A SPRAY OF WATER DROPS.
D.S.I.R.3529b.

311. Cessna, O. C., Lienz, J. R., Trans.Amer.Inst.Chem.Engrs.36 759-780.
Badger, W. L. 1940.
HEAT TRANSFER IN A LONG TUBE VERTICAL EVAPORATOR. 4th paper in the series on this subject. Previous Papers Tr.Amer.Inst.of Chem.Engrs. (1) 33 392 1937 - Brooks and Badger. (2) 35 17 1939 - Stroebe Baker and Badger. Chem. & Met. Eng.g. (3) 46 640. 1939. W. L. Badger.

312. Claessen, H. Zucker Ind.1.55 1943. Zeit.Ver.Deutch. Engrs.210.1943.
CALCULATION OF HEAT TRANSFER SURFACE IN HEAT EXCHANGES. Coefficients realised in practice are often much lower than those on which the calculations for heat transfer are based. (Refers to sugar juice evaporators).

313. Comings, E. W., Clapp, J. T., Ind.Eng.Chem., 1948, 40, 1076-1082.
Taylor, J. F.
TURBULENT AIR STREAM: HEAT TRANSFER RATE. Measurements have been made of the effects of fluid turbulence on heat and mass transfer rates from a cylinder normal to an air stream. Increased turbulence at a constant Reynolds number caused a maximum of 25 per cent. increase in the rate of heat transfer. The transfer rates were augmented by increased turbulence at larger Reynolds numbers, but this effect was negligible at smaller numbers. In the range tested (Re400 to 20,000) baffles arranged to increase the local velocity near the cylinder were more effective in increasing the transfer rate than were those arranged to increase only the level of turbulence.

314. Cope, W. F. Abstr. of pap. to Seventh Internat.
Congr. Appl. Mech., Sept. 1948.
HEAT TRANSFER AT HIGH SPEEDS. The heat transfer between a flat plate and a stream of gas flowing at any Mach number is calculated and it is shown that the rate of heat transfer is proportional to the difference between the temperature of the plate and the temperature (sometimes called the "natural" temperature) the gas would have attained at the plate if there were no heat transfer. The case actually proved is that of a uniform stream but reasons are adduced for thinking that the result is true both when there is a pressure gradient and for turbulent flow. An example of the numerical effect of the proper interpretation of existing formulae (Pohlhausen's) is given.

315. Drew, T. B., Hottel, H. C., Amer.Inst.of Chem.Engrs.Trans. 32
McAdams, W. H. 271-305.
HEAT TRANSMISSION. Basic Laws. Includes Table of organic compounds and their effect in promoting dropwise condensation of steam on metal.

316. Fatica, N., Katz., D. L. Chem.Engng.Progr., 1949, 45, 661-674.
DROPWISE CONDENSATION. A mathematical analysis assumes that the area occupied by drops is a constant fraction of the heat-transfer surface, and that the conductivity through the drops is a function of maximum drop size. This in turn is a function of wetting angle and inclination of surface to the vertical. A theoretical value for the total coefficient of heat transfer can be obtained. Fully-formed droplets, however, rolling down the surface, leave a swept track behind and normally coalesce, on a surface of > 4 in. in depth, to give an even film (normal film condensation). The high conductivity of this track will give an effect comparable to a diminution in maximum drop size. An experimental condenser was built with an optical system to determine contact angles of drops. Simultaneous measurements of heat transfer and of contact angles were made with a variety of prepared surfaces. The theoretical formula held if the droplet size figure was multiplied by a factor of 0.[illegible] to correct for

the "sweeping" effect. The original drop nucleus is set up at a break in a hydrophobic film, unrelated to any active points in the surface below.

317. Fishenden, Saunders H.M.S.O. 1932.
CALCULATION OF HEAT TRANSMISSION.

318. Fitzpatrie, Baum, Trans.Amer.Inst.Chem.Engrs.35 97.109.
McAdams, Emmons. 1939.
Includes a treatment of dropwise V.S. filmwise condensation.

319. Garcia, J. O. Rev.Cienc.apl.3 161-171.1948.B.I.158.
March 1949.
TRANSMISSION OF HEAT BY CONVECTION. Heat transmission by convection is examined from the view-point of dimensional analysis. The results are applied to forced convection, natural convection, vapour condensation and the boiling of liquids.

320. Gelissen, H. C. J. H. Industr.Heat.,15,402,1948.
DEVELOPMENT OF THE BEUKEN MODEL FOR ANALYSIS OF UNSTEADY-STATE HEAT TRANSFER. It is stated that only three models have been built for the study of the unsteady-state heat transfer. The first, built by Dr. Beuken in Holland in 1934, has served as a basis for the two later models, which are those of Dr. Paschkis at Columbia University, and of Dr. Fischer in Germany during 1938. The Beuken model is briefly described. It has been used mainly in problems connected with the construction and operation of intermittently-operated electric furnaces, whereas the Fischer model appears to have been concerned mainly with intermittent space heating. In the U.S.A. the application seems to be incidental, as a great number of applications deal with other problems; an advantage of this model, however, is that it permits determination of unsteady-state tridimensional heat transfer. (4 figs.)

321. Gilbert, W. S. Engineer Vol.150.1931. Series of Papers.
THE HEATING AND DRYING OF GRANULAR MATERIALS BY CONVECTION. See under "ROTARY DRYERS.

322. Hampson, H., Ozisik, N., Mech.Eng.Res.Org.D.S.I.R.1949.
Fang, C. C.
Unpublished report (10 pp.) of an investigation into condensation, dropwise and filmwise, carried out at Queen Mary College. Film.

323. Harbert, W.D., Cain, D.C., Ind.Eng.Chem.33 257.1941.
Huntington, R. C.
UNSTEADY FLOW OF HEAT THROUGH POROUS MEDIA. Sand, and mixtures with glass spheres of 5/8 inch and 5/16 inch diam. were used with oil as the fluid. Data shew that conduction operates for small grains and convection becomes prominent for large grains. Temp. V.S. time

curves are given for the various conditions of grading. Temperatures were below 200°F.

324. Jaeger, J. C. Phil.Mag.1944,35,169; Brit.Ceram.Abst. 1944,163A.
SOME PROBLEMS INVOLVING LINE SOURCES IN CONDUCTION OF HEAT. A solution is sought to the problem of the temp. distribution due to a line source of heat parallel to the axis of a cylinder consisting of two shells of different materials. The solution is carried out in cylindrical co-ordinates by the Laplace transformation method. The problem of the uniform rotation of a source of heat round the surface of a cylinder is also examined.

325. Jakob, M. Proc.Phys.Soc.,1947,59,726-755.
HEAT: TRANSFER MECHANISMS. A survey of heat transfer by radiation, conduction and convection is presented. Under the heading heat radiation, a derivation of the basic law of gas radiation and a photographic and photometric model method for the determination of surface and gas radiation are considered. Under heat conduction, the author discusses temperature distribution in the walls of boiler tubes, in electrical coils due to a linear increase of Joulean heat with temperature, and in bodies of simple form developing or absorbing heat at a linear function of temperature. Studies on free heat convection are reviewed, and heat transfer to a fluid in laminar flow through an annular space, forced heat convection in laminar and turbulent flow parallel to a surface, and forced heat convection in turbulent flow against a surface are considered. There are 29 references to the literature.

326. Jensen, H. H.
SOME NOTES ON HEAT TRANSFER BY RADIATION. See under "INFRA-RED.

327. Jurgenson Jr., D.F., Montillon, G.H. Ind.Eng.Chem.27(12) 1466-1475 Dec.1935.
HEAT TRANSFER COEFFICIENTS ON INCLINED TUBES. Many tables of experimental data.

328. Kettering, K.M., Manderfeld, E.L., Smith, J.M. Purdue Univ. Lafayette Chem.Eng.Progr.46(3) 139-45. Mar.1950.
HEAT TRANSFER AND MASS TRANSFER OF WATER VAPOUR IN FLUIDISED GAS STREAMS. Experiments on Silica Gel and Activated Alumine at various sizes, and rates of flow of gas.

328a. Lander, C. H. Inst.Mech.Engrs.Preprint.Apr.1942.
REVIEW OF RECENT PROGRESS IN HEAT TRANSFER. Points reviewed. Emissivity and a comparison between theoretical and practical determinations. Radiation from gases. Natural and forced convection. Relation between Heat Transfer and Fluid Friction. Heat Transfer between a stream of gas and a solid bed. Heat transfer to boiling

liquids from Condensing stream. Evaporation and relation to convection. Each section has a bibliography.

329. Lapp, K. Archiv. fuer Waermewirtschaft (Berlin), vol. 11, No. 10, Oct. 1930, pp. 341-342, 1 fig.
AIR AND RESIDUAL WATER IN STEAM DRIERS (LUFT UND RESTWASSER IN DAMPFTROCKNERN). Injurious effect of air and residual water on heat transfer in steam driers; determination of air volume admitted; new method and equipment for eliminating this trouble.

330. Ledoux, E. Chem. Publ. Co. 1949 Brooklyn.
Graphical solution of Heat and Vapour Transfer Problems.

331. Leva, M. Ind. Eng. Chem. 39 (7), pp. 857-62. 16.7 1947.
Heat transfer to gases through packed tubes. Correlation for smooth spherical particles. Equations. Curves. Tables.

332. Lof, G. O. G., Hawley, R. W. Industr. Engng. Chem., 40, 1061, 1948.
UNSTEADY-STATE HEAT TRANSFER BETWEEN AIR LOOSE SOLIDS. Only meagre data are available for the design of equipment employing heat transfer from a flowing fluid to a bed of loose solids. In this investigation, design data in the form of unsteady-state heat transfer coefficients from air to a bed of granitic gravel are presented. The size of gravel employed ranged from 4-mesh to 1.5 in.; air rates from 12.05 to 66.3 standard cu. ft/min/sq. ft. of cross-sectional area were used; and the entrance air temperatures maintained were over the range 100°-250°F. The gravel was packed into the bed in such a manner that normal voids were obtained. It was found that the results could be correlated by the equation: $h = 0.79\left(\frac{G}{D}\right)^{0.7}$ wherein h is the heat transfer coefficient at a given point and time in B.Th.U/hr/cu.ft. of bed volumes/° Fahrenheit difference between air and solid at the given point and time; G is the air flow rate, lb/hr/sq. ft. of bed cross-section; and d is the equivalent spherical diameter of the particles in feet. Change in temperature of the entering air had no appreciable effect on the coefficient. (10 figs., 2 tables.)

333. Logan, Fragen, Badger. Ind. Eng. Chem. 26 1044-7 1934 8 Refs.
LIQUID FILM HEAT TRANSFER. Coefficients in a vertical tube forced circulation evaporator.

334. McAdams, W. H. Trans. Amer. Inst. Chem. Engrs. 36 pp. 1-20. 1940.
REVIEW AND SUMMARY OF DEVELOPMENTS IN HEAT TRANSFER BY CONDUCTION AND CONVECTION.

335. McAdams, W. H. McGraw Hill Co. 1942 2nd Ed.
HEAT TRANSMISSION. Includes rational analyses of most types of heat transfer problems.

336. Mc.Adams, W. H. Chem.Eng.Progress 46(3) 121-130.Mar.1950
First Institute Lecture, 1949.
HEAT TRANSFER. This is the first in a series of Unit Operations reviews, and covers (a) fundamentals of several types of heat transfer, (b) summarises recent developments, (c) outlines the needs for further work. 101 Refs.

337. Milnes, A.
Heat transfer at the Paper rolls, see under Paper.

338. Nagle, Bays, Blenderman and Drew Trans.Amer.Inst.Chem.Engrs.31 593.1935.
Heat load has not much influence on the coefficients of heat transfer when dropwise condensation occurs.

339. Ordinarz, W. Schweiz.Arch.Angew.Wiss.Techn.10 113-15, 1944.Br.Abstr.A 47 232.1944.
NEW METHOD OF CALCULATING HEAT EXCHANGE BY RADIATION.

340. Othmer, Meisenberg, Boarts, Bodger Ind.Eng.Chem.21 576.1929 Trans.Amer.Inst. Chem.Engrs.31 622.1935.
Deals with heat transfer between condensing vapours and solid surface, and the effect of the presence of air in the vapour space.

341. Roberts, A. J.
HEAT AND THERMODYNAMICS 1949.
pp. 218-229. Transfer of Heat by conduction and convection.
pp. 229-245. Metals.
pp. 245-49. Natural Convection.
pp. 250-51. Forced Convection.

342. Rössler, F. Bergban u. Energiewirts.1 165-169.1948.
B.I.313.May 1949.
HEAT TRANSFER (FROM AIR) TO WET SURFACES AND EVAPORATION THEREFROM. The rate of heat transfer is the resultant effect of heat conduction through a boundary layer and evaporative cooling controlled by diffusion. Values for a total transfer coefficient for air and wet or icy surfaces applicable to the cooling of wet animals or plants. Assman psychrometer readings, sea and land temperature in wind, the mucous membrane of the lungs are plotted. The coefficient can be modified so as to give mass rates of evaporation.

343. Saunders Trans.Inst.Chem.Engrs.8.209.1930.
HEAT TRANSFER CALCULATIONS.

344. Schulze-Manitius, H. Feuerungstechnik, vol.19,No.8,Aug.15, 1931,pp.121-127,5figs.
DAMPF-LUFT-GEMISCHE (STEAM-AIR MIXTURE). Diagram for steam-air mixture; heat balance of drier under different drying conditions; process of recooling; tables of saturation pressures for steam.

345. Shea, Jr., F.L., Krase, N.W. Trans.Amer.Inst.Chem.Engrs.36 463-490
1940.
DROP-WISE AND FILM CONDENSATION OF STEAM.

346. Skaperdas, G. Ind.Eng.Chem.Jan.1946-47-48-49-50.
UNIT PROCESS REVIEWS, HEAT TRANSFER. Bibliographies.

347. Thiele, E. W. Ind.Eng.Chem.1946 38 646-50.
REVIEW OF MASS AND HEAT TRANSFER BETWEEN GRANULAR SOLIDS AND
FLOWING FLUIDS.

348. Walker, Lewis, Principles of Chem.Eng.1937 Chap.4
McAdam, Gilliland p.100-167.
FLOW OF HEAT. All aspects of heat flow are considered, including
radiation. Incl. Filmwise and dropwise condensation. (70% increase
in heat transfer coefficient by dropwise condensation.)

349. Wilson, A. C. Ind.Heating Engr.1948.10 42. 134-6.
Heat Transfer Data and curves. Paper read 17.3.48 at special meeting
of Inst. of Heating and Ventilating Engineers.

HUMIDITY. HYGROMETRY

350. —— British Standards Assn.No.1339.1946.
J.Sci.Insts.24 305 Nov.1947.
HUMIDITY OF THE AIR. DEFINITIONS, FORMULAE AND CONSTANTS. The
terms recommended for use in hygrometric measurement are defined,
and simple formulae given for various purposes. Each formula is
accompanied by a table of constants for the various systems of units.

351. Anon Instruments Jan.1946.Packaging Abstr.
1932.1946.
HYGROLABELS. These are small sensitive labels smaller than a postage
stamp, which change colour with humidity. The change is distinct and
reversible, brilliant blue green when dry, and pink when humidity is
high enough to cause mould growth, corrosion etc. They are adhesive,
with a protective removable backing.

352. —— Proc.Phys.Soc.1921-22 34 Special
Section 94 pp.
A discussion on Hygrometry held at Imperial College, South Kensington
25th November, 1921 Papers:-
Measurement of Atmospheric Humidity. - Sir Hapier Shaw.
Some modified forms of Hygrometer. - Ezer Griffiths.
40 pages dealing comprehensively with methods and measurements.
5 main types of hygrometer are described, and an apparatus for

obtaining variable humidity. Low temperature methods.
An appreciation of the various types of hygrometer.

The Theory of the Hair Hygrometer. –	F. J. W. Whipple.
The Rationale of Glaisher's System of Hygrometry.	F. J. W. Whipple.
The Wet and Dry Bulb Hygrometer. –	S. Skinner.
Note on Psychrometry in a Wind Channel.	R. A. Watson Watt.
The Tilting Hygrometer	H. G. Mayo, A. M. Tyndall.
A Thermal Hygrometer	A. M. Tyndall, A. P. Chattock.

The papers referred to the uses of the instruments and purposes for which they were constructed. Discussion. 13 pages, and a list of exhibits, mainly those of Dr. Griffiths and those used for meteorological purposes.
Bibliography, 50 Refs., appertaining to each type of instrument and compiled by Dr. E. Griffiths.

353. ---- Br.Jute Trades R.A.Bull.Vol.2.No.9 Apr.1950.
The use of wet and dry bulb hygrometers and the relative humidity in industrial buildings.

354. Anon Textile Manufacturer, 1940, 66, 21-23.
TEMPERATURE, HUMIDITY AND pH MEASURING AND CONTROLLING INSTRUMENTS. The value of instrumental control in the textile industry, especially in connection with air-conditioning, the control of the temperatures of baths used in wet processes, drying cylinders, calendar bowls, etc., and pH determinations, is discussed and various types of instruments available for such purposes are briefly described.

355. ---- National Physical Lab. 1935.
AN APPARATUS FOR CONTROLLING THE WATER VAPOUR CONTENT OF THE ATMOSPHERE IN A DRYING CHAMBER (at 100°-130°C). D.S.I.R. 114 j/a.

356. ---- Heating and Ventilating p.50.June, p.64 July, p.59 Aug.1931.
REVIEW OF PSYCHROMETRIC CHARTS.

357. Apjohn, J. Trans.Royal Irish Acad. 17 275-292.1837.
ON THE THEORY OF THE MOIST BULB HYGROMETER. The conclusions made in an article on hygrometry in Brewster's Encyclopaedia are criticised. An analysis, mathematical, of the wet bulb phenomena is attempted and an experimental verification of the formula. The method of inferring the dew point from moist bulb readings is described and results embodied in tables.

358. August, E. F. Annalen der Physik und Chemie. Poggendorff 5 69-88. 1825.
THE FALL IN TEMPERATURE ON EVAPORATION OF WATER AND ITS APPLICATION TO HYGROMETRY. (Transl. title). A formula is derived relating to the wet and dry bulb thermometer.

359. Awbery, J.H., Griffiths, E. Proc.Phys.Soc.44 132.1932.
LAW OF THE WET AND DRY-BULB THERMOMETERS FROM 40°C to 100°C.
Gives a short table of R.H. from 30°C to 100°C.

360. Awbery, J. H. Proc.Phys.Soc.Lond.44, 143, 1932.
HUMIDITY OF SATURATED AIR UP TO 100°C.

361. Awbery, J. H. J.Sci.Instr., 20, 153, 1943.
NOTES ON SOME RECENT DEVELOPMENTS IN HYGROMETRY. Fundamental methods of measuring humidity are by direct weighing and by the dew point determination. There has been little alteration in the former method, but attempts have been made to detect the formation of dew by photo-cells. The theory of the wet and dry bulb hygrometer remains incomplete, and the method is therefore not absolute. Other instruments discussed are the hair hygrometer and the related cellophane hygrometer; the glycerine hygrometer depends on the change in R.I. of this liquid as it takes up water. A new instrument depends on the change in surface conductivity of glass with changes in humidity; several modifications of this are described. Discussion. H. H. Macey (Ibid., p. 199). Attention is drawn to the unreliability of the hair hygrometer at temps. above 100°F.

362. Bell, G.H., de V. Weir, J.B. Brit.Med.J., 1947, 2, 174 (through Brit.Abstr., 1948, A.III, 955.
RELATIVE HUMIDITY NOMOGRAMS. Values given by Wynne's simplified formula for relative humidity and drying capacity of the atmosphere can be read off direct on the nomograms illustrated in the text, no calculation being required. The charts are based on the exact values of the partial pressure of water vapour under saturated conditions and have the additional advantage that both Fahrenheit and Centigrade scales are incorporated. The nomograms are designed for use in calm conditions such as exist in buildings.

363. Berry, C. H. Combustion 6 15-18, 24-26, 21-24 Aug. Sept. and Oct. 1934.
HUMIDITY CALCULATIONS. The accuracy of humidity computations. Comparison of psychrometric charts. A simple method for calculating humidity.

364. Carmann, J. Stahl u. Eisen, 53, 94 (1933) Jan. 26.
MOISTURE DETERMINATION. Contribution to measurement of humidity in gases; method for continuous determination of condensing and absorbing constituents in flowing gas mixtures, known as binary mixture measuring method. (In German).

365. Carrier, W. H. Trans. Am. Soc. Mech. Engrs. 33 1005-1036 1911.
RATIONAL PSYCHROMETRIC FORMULAE. Their relation to the problems of meteorology and air-conditioning. Proof and derivation of formulae Discussion. 1039-1053.

366. Carruthers, J. L.
HUMIDITY CALCULATIONS. See under Ceramics.

367. Cassie, A. B. D. Proc. 3rd Textile Teachers Conference April 1945 1-6.
ATMOSPHERIC HUMIDITY. Methods are given for defining the conditions of a humid atmosphere in terms of measurable quantities. Indoor and outdoor humidities are compared.

368. Cherry, R. H. Analyt. Chem. 20 958-964 1948.
DETN. OF WATER VAPOUR. THERMAL CONDUCTIVITY METHODS. The detn. of water vapour in gases is discussed. Recording equipment of this type can be made to have excellent constancy of calibration and zero stability. The useful dew point range for water vapour in air is $-18^{o}C$ to $50^{o}C$ and from $80^{o}C$ upward. A saturator capable of delivering gas having a water vapour concentration constant to ± 0.01% by volume is described.

369. Davis, D. S. The Chem. Engrs.' Plant Notebook 45-6.
NOMOGRAPHIC SOLUTION OF HUMIDITY CONVERSIONS.

370. Dropkin, D. Bull Cornell Univ. Eng. Exp. Stn. No. 26, 1939 60 pp. (Sci. Abstr. A43 186-1940.
WET AND DRY BULB THERMOMETER EFFECT OF RADIATION. From expts. on radiation on the readings, a formula is presented for calculating the true dry bulb temperature from data on temperature of walls, air velocity, dimensions of bulb. Similarly for wet bulb temperature. The radiation error can be expressed as a % of wet bulb depression without knowing the wet bulb temperature.

371. Dropkin, D. Mech. Engng., 1940, 62, 145-146.
WET-AND-DRY BULB THERMOMETERS: COMPUTATION OF EFFECTS OF RADIATION. Equations are presented for correcting dry-bulb and wet-bulb temperatures for the effects of radiation.

372. Dropkin, D. Mech. Eng. 63 369-70. 376. 1941.
PSYCHROMETRY. HISTORY. Brief review of development by Baume etc., during the period 1758-1877.

373. Ebaugh, N. C. Combustion 22-3(1934) Dec.
AIR DENSITY FORMULA AND CHART BASED ON MODIFIED APJOHN EQUATION.

374. Ebert, H., Pfeiffer, A., Zamerhof, S. Gesundheitsing., 1938, 61, 596. Chem. Abstr., 1939, 33, 502.
COOLING BY EVAPORATION AND A NEW METHOD FOR THE ACCURATE MEASUREMENT OF ATMOSPHERIC MOISTURE (transl. title). A brief critical review and comparison of psychrometric and absorption methods.

375. Ebert, H. Z. Physik 76, 163-71 (1932).
THE CONCEPTION OF RELATIVE HUMIDITY, ESPECIALLY AT HIGH TEMPERATURES. The humidity may be defined in various ways which for ordinary temperatures lead to the same results but at temperatures above 300^{0} give rise to appreciable deviations. This results in variations between different psychrometers. A method of correcting for these deviations is given.

376. Frith, J., Buckingham, F. Engineering v 134 n 3483 Oct. 14 1932
p.460 3 and (discussion) 437.
THEORY OF DRYING. Problem of drying; theory of wet-bulb thermometer; wet-bulb thermometer as measure of total heat of any mixture of air and water vapor; relative humidities per cent. calculated from theory. Before Brit. Assn.

377. Fritz Z.ges.Kalte Ind. 38 (1931).
HUMIDITY DETERMINATION.

378. Graeffe, J. Rayonne 5 (3) 147-149. March 1949.
MEASURE DE L'HUMIDITÉ DE L'AIR. Elementary Treatment of Hygrometry and Methods of Measurement.

379. Hatta, S. J. Soc. Chem. Ind., Japan 36, 354-63, B (1933).
HUMIDITY CHART APPLICABLE TO MOST INDUSTRIAL GASES.

380. Hatta, S. J. Soc. Chem. Ind. Japan 37, 65-7B. 1934 Feb.
NOMOGRAPH FOR PERCENTAGE vs. RELATIVE HUMIDITIES OF GASES.

381. van der Held, E. F. M. Gesundheitsing., 1937, 60, 741. Brit. chem. physiol. Abstr. B, 1938, p. 467.
THE HYGROMETER CONSTANT (transl. title). The constant is calculated on the basis of modern views of heat transfer, air flow and evaporation. The effects of radiation and of the conductivity of the supports are discussed.

382. Hensley, R. V. (U.S. Nat. Adv. Comm. Aeronaut., Tech. Note No. 1715, Sept. 1948, 16pp.
MOLLIER DIAGRAMS FOR AIR SATURATED WITH WATER VAPOUR AT LOW TEMPERATURES. Temperatures of 400^{0} to 540^{0} R. and pressures of 2-28 p.s.i.a. are covered. Vapour-liquid and vapour-solid equilibrium are treated. Examples illustrating use of the charts in the solution of thermodynamic problems involving wet air and ice are given.

383. van Hoestenberghe, R. Union des Ingenieurs Sortis des Ecoles Speciales de Louvain-Bull. n 3 1935 p 67-85.
CONSIDERATIONS FONDAMENTALES SUR L'EVAPORATION ET LA PSYCHROMETRIE; ETC. Fundamental consideration of evaporation and psychrometry;

application to calculation of drying equipment; theoretical mathematical design analysis and practical examples of their application

384. van Hoestenberghe, R. L. Tech. Wet. Tijdschr., 1941, 10, 279. Bull. int. Inst. Refrig., 1942, 23, 81.
FUNDAMENTALS OF THE DRYING TECHNIQUE AND ITS APPLICATION TO INDUSTRIAL DRYING (transl. Title). A study was made of the laws which govern the adiabatic evaporation of water into air. The influence of hygrometric conditions during drying is emphasized. Different methods of measuring the moisture content of the air are dealt with. The laws of evaporation are applied to industrial drying.

385. Johnstone, H. F., Silcox, H. E. Ind. Eng. Chem. 39 808 1947.
ABSORPTION AND HUMIDIFICATION IN CYCLONE SPRAY TOWERS.

386. Kamei, S. Chem. Fabrik 337-9 (1932) C. A. 26, 4658.
THE NEW HUMIDITY CHART.

387. Kirschbaum, E., Lise, J. Chemie-Ing. Tech. 21 89-92, 92-94. 1949.
K. has redefined the wet-bulb cooling equation to take into account the heat required to raise the temperature of the evaporated water to the dry bulb temperature. The correction is small for ordinary temperatures. The psychrometric ratio of water-air mixtures was evaluated by using these new equations, from experimental data taken up to 67°C. dry-bulb temperature (2nd paper). The measured psychrometric ratio divided by the humid heat of the air ranged from 0.84 to 0.94 over the temperature range 20°-67°C.

388. Koch, W. J. Sci. Instruments, 1945, 22, 94-95.
HAIR HYGROMETER ADJUSTABLE SCALE. A method is described for constructing and using a scale which compensates fairly well for calibration errors. The principle involves the use of three fixed points; the appropriate scale reading is determined by the intersection of a movable line with an arc passing through each point on the scale. The line is adjusted by reference to the fixed points. An application to a hair hygrometer is considered.

389. Krivochew, S. A. Zavod Lab. 3, 368 (1934) Abst. in J. Soc. Chem. Ind. 53, 656 (1934) Aug. 3.
DETERMINATION OF HUMIDITY OF GASES FROM THE PARTIAL WATER VAPOR PRESSURE. Humidity is calculated from the fall in pressure after absorption of H_2O vapor.

390. Leslie, J. Nicholsons Journal, 3 461-467, 1800.
DESCRIPTION OF A HYGROMETER AND PHOTOMETER. An evaporating substance does not lose heat indefinitely, but must at last, receive heat exactly in proportion to its loss, from the air. Therefore to discover the humidity of the air, it is only necessary to measure the change in temperature of a body of water (the principle already

established by Leslie in 1790). The instrument was a cup of Wedgewood's bibulous biscuit ware, whose temperature could be measured by thermometer while its absorbed water was evaporating, and compared with that of the surrounding air.

391. Mackey, C. O. — Heating and Ventilating, August 1930, Vol.27, No.8, p.65.
HUMIDITY - SPECIAL SLIDE RULE FOR PSYCHROMETRIC CALCULATIONS.

392. Mackey, C. O. — Heating and Ventilating 29, 40, 43 (1932) Mar.
THE LABUS HUMIDITY CHART.

393. Manning, C. E. — Proc.N.Z.Ass.Refrig.Inc., 1939, 7, 57 and 83.
CONTROL OF HUMIDITY. Discusses in simple terms the basic principles involved in atmospheric humidity control and describes typical methods of regulating the humidity of air in enclosed spaces. Methods commonly used in dehumidification (cooling below dew-point temperature, chemical absorption and solid absorption) and humidifying air (steam jet, atomized water spray and pan type humidifier) are considered.

394. Marsh, M. C. — J.Soc.Chem.Ind., C.& I. 53, 671-8 (1934) Aug. 3.
AIR CONDITIONING IN INDUSTRY: A REVIEW OF POSSIBLE DEVELOPMENTS. M. gives a general discussion of methods for humidity measurement and control.

395. Clerk, Maxwell — 9th Edition of Encycl.Brit. (1877).
THEORY OF THE WET-BULB THERMOMETER. Gives Apjohn's "Convection" Theory as well as his own "Conduction" Theory.

396. Normand, C. W. B. — Indian Meteor Memoirs - Vol.XXIII, PT.1, p.1-22.
WET-BULB TEMPERATURES AND THERMODYNAMICS OF THE AIR. (See also Humphreys - Physics of the Air). Adiabatic cooling process leads to same constant in psychrometric formula as is determined by experiment, on theoretical proof of use of adiabatic cooling lines for wet and dry bulb hygrometer.

397. Osborne, N. S. et al — Amer.Soc.Mech.Engrs. 55 Research Papers 51-66, 1933.
THE PRESSURE OF SATURATED WATER VAPOUR IN THE RANGE 100°C to 374°C. Tables. Methods of Measurement.

398. "Polytrope" — Mech.World. 118 618-20 1945.
MIXTURE OF AIR AND WATER VAPOUR AT ATMOSPHERIC CONDITIONS. CHARACTERISTIC DATA. III. 2 Charts shewing total heat and quantity of vapour at various R.H.s and temperatures, for quantities of water varying from 0 to 0.4, and 0 to 0.10 lb. per lb. dry air. A third

chart correlates R.H., Temperature, and quantity of water vapour contained in moist air at any total pressure.

399. Regan, R. F. Refrig. Air-Condit. (Canada), 1947, 3 (No. 1), 19.
PSYCHROMETRY. Deals with the solution of thermal problems associated with cooling, drying, humidifying or dehumidifying air and presents a psychrometric chart.

400. Rice, W. T. Chem. Eng.ng. 55 (10) 116-1948.
HUMIDITY. SIMPLIFIED CALCULATIONS. A chart is given relating air pressure, dry bulb temperature, R.H., and dew point. Description and example of the use of the chart for calculating changes involved in the compresion of air.

401. Ringquist, C. L. Univ. of Illinois Bull. 36. 58-71 1939.
Building Sci. abstr. 13 63-4 1940.
AIR TEMPERATURE AND HUMILITY CONTROL DEVICES.

402. Robitsch, M. Z. Instrumententek. 52 80-5. 1932.
THEORY OF THE PSYCHROMETER. A mathematical paper.

403. Scholtz, M. Melliand Textilberichte 13, 171-4 March, 229-31 April, 287-88 May. (1932).
USE OF MOLLIER HUMIDITY CHART IN SOLVING PROBLEMS OF AIR CONDITIONING AND DRYING.

404. Shields, C. D. Refrig. Engng. 1939, 38, 293.
MIXTURES OF AIR AND VAPOUR AT TEMPERATURES BELOW FREEZING. A discussion of psychrometric phenomena relating to air-vapour mixtures at low temperatures. Tables and a psychrometric chart show the properties of mixtures of air and saturated water vapour over ice and sub-cooled water and ethalpy of ice and low temperature water vapour.

405. Skinner, S. Phys. Soc. Lond. 34 No. 192. p. I-XCV 1922.
Symposium on Theory. Note - p.9(41).
THE WET AND DRY BULB HYGROMETER. Gives Theory of G. I. Taylor. Discussion by A. H. Davis who gets Maxwell formula by dimensional analysis p. lxxxv. Discussion by Whipple p xci refers to work of Taylor on liquids other than water. Bibliography by Griffiths p xciv. Ivory 1822, August 1825, Apjohn 1834, Belli 1838, Regnault 1845.

406. Stansfield, E. Canad. J. Res. 21 A51-55 1943.
HUMIDITY DATA; TABLES, AND NOMOGRAMS.

407. Steffes, M., Welter, R. Chaleur and Industrie v 15 n 174 Oct. 1934 p 266-8.

L'INFLUENCE DE L'HUMIDITE SUR L'ETAT PHYSIQUE DES GAZ. Influence of humidity on physical condition of gas; equations for perfect gas; mixtures of gas and steam; physical state of water vapor; hydrometric state of gas; reduction of normal dry state of gas; reduction of normal dry state of volume of humid gas; calculation of specific weight of humid gas.

408. Stokes, R. H. Brit.Chem.Digest,1948,2,335-337 (from Australian Chem.Inst.J. and Proc.,1948, 15,No.1.).

AQUEOUS SOLUTIONS: VAPOUR PRESSURE MEASUREMENT. The more important methods of vapour-pressure measurement in the concentration range above 0.1 molal are classified into primary methods, including (i) the direct measurement of the vapour pressures by some sort of manometer and (ii) the measurement of the weight of vapour required to saturate a known volume of a carrier gas passed through or over the solution ("dynamic" method and secondary methods, comprising (iii) the isopiestic comparison method of Robinson and Sinclair, (iv) various modifications of the dew-point method, and (vi) a method recently developed by the author called "bithermal equilibration through the vapour phase". Methods (iii) and (vi) are discussed more fully.

409. Strock, C. Industrial Press N.Y. 1948.

HEATING AND VENTILATING ENGINEERING DATA BOOK. 57 pp. on Psychrometry.

410. Todd, F. C., Gauger, A. W. Proc.Amer.Soc.Testing Materials,1941,41, 1134-1151.

WATER VAPOUR: MEASUREMENT IN GASES. To facilitate the comparison of measurements of the moisture content of gases by the many methods now in use, two methods are presented for the measurement of the absolute moisture content of fuel gases. These methods are applicable to both manufactures and natural gas with the impurities normally found in them. The absorption of radiation near 1.87 (18,700A) by water vapour is employed for a laboratory method. The sensitivity of equipment built for the infra-red spectrophotometric method is shown to be of the order of 0.25 per cent. of the relative humidity at 22°C., but the effects of all the impurities have not been determined. In the portable colorimetric method for field use, fractions condensable from the gas at - 70°C. are removed from an accurately measured quantity of gas and the condensate mixed with an indicator solution of cobaltous bromide in n-butyl alcohol. The colour of the indicator solution depends on the amount of water, the amount of nonaqueous condensate and its colour, the solubility of water in the condensate, and the temperature of the indicator solution. An instrument for making the colorimetric measurements is described and correction methods are outlined for the above variable. The reproducibility of the measurements is discussed and shown to be good.

411. Van Wazer, J. R. Anal.Chem.21 1242-3.1949.
Heyden Chem.Corp.
HUMIDITY TESTING CABINET AND IMPROVED HUMIDITY REGULATOR. Diagram of a thermohumidistat constructed from a refrigerator cabinet. Equipped with electric heaters an air circulatory system and a humidifier. The humidity control was accomplished by using a moisture sensitive resistor and a symplytrol meter relay. When set for 100°F. and 90% R.H., the variation in wet and dry bulb was not more than 0.2°F..

412. Wexler, A. Jnl.Res.of Nat.Bur.Stds.45(5) 357-361
5 Nov.1950.
RECIRCULATING APPARATUS FOR TESTING HYGROMETERS. Apparatus and principles described, in which air is saturated at a low temperature, and raised to a known temperature (and therefore known R.H.) in continuous circulation. Arrangements for rapid change of humidity. (1-2 secs.).

413. Whipple, F. J. W. Proc.Phys.Soc.(London)45,307-9(1933, March 1).
THE WET AND DRY BULB HYGROMETER: THE RELATION TO THEORY OF THE EXPERIMENTAL RESEARCHES OF AWBERY AND GRIFFITHS.

414. Winborn, Jr., B. R. Refrig.Engng.1941,42,179.
HIGHLIGHTS OF WET-BULB THERMOMETRY. Gives an historical review of developments in the theory and use of the wet-bulb thermometer for indicating the humidity of the air.

415. Zimmerman, O.J., Levine, Irvine Industrial Research Service.
Dover.New Hampshire 160 pp.1945.
PSYCHROMETRIC TABLES AND CHARTS. 32 tables. 22 charts. Prefaced by 10 pages dealing with theoretical aspects of humidity etc., and a guide as to the use of the tables and charts.

Control Solutions

416. Carr, D. I., Harris, B. L. Ind.Eng.Chem.41(9)2014-5.Sept.1949.
SOLUTIONS FOR MAINTAINING CONSTANT RELATIVE HUMIDITY. 12 salts. R.H.'s of saturated solutions in temperature range 15°C to 90°C. Alkali halides nitrites, nitrates, chromates.

417. O'Brien, F. E. M. J.Sci.Instrum.,25,73,1948.
THE CONTROL OF HUMIDITY BY SATURATED SALT SOLUTIONS. A table of data gives percentage relative humidities over saturated solutions of [illegible] different salts or salt mixtures. Remarks on the suitability of these solutions for humidity control are included. (1 table).

418. Stokes, R.H., Robinson, R.A. Ind.Eng.Chem.41(9)2013.Sept.1949.
STANDARD SOLUTIONS FOR HUMIDITY CONTROL at 25°C. Sulphuric acid, Caustic soda, Calcium Chloride.

419. Williams, G.C., Williams, R.J. Industr. Engng. Chem. 1943, 35, 730.
HUMIDITY MEASUREMENTS IN PRESENCE OF WATER-SOLUBLE SALTS. A theory is advanced to explain the observed rise in wet-bulb temperature when measured in atmospheres containing water-soluble salts. Procedure is suggested for a rapid and simple approximation of the true wet-bulb temperature from the observed value. Present experimental data on 4 water-soluble salts over a dry-bulb range of 80°C and a corresponding wet-bulb range of 40°C. Experimental values of salt solution wet-bulb temperatures were converted to water wet-bulb temperatures and showed substantial agreement with experimentally determined water wet-bulb values.

420. Williams, G.C. and Schmidt. Ind.Eng.Chem. 1946, 38 967-974.
HUMIDITY CHARTS FOR SALT SOLUTIONS. Theory of rise in wet bulb temperatures with salt solutions.

INSTRUMENTS. HYGROMETRIC

General

421. Anon — Arch.Tech.Messen.Jan.1949.Bull.Br.Sci. Inst.Res.Ass.5 22 Jan.1950.
RECORDING INSTRUMENTS FOR TEMPERATURE AND HUMIDITY. A survey is given of the range of instruments made by the German firm Lambrecht, of Gottingen. Particular reference to thermographs and thermohydrographs.

422. Anon (Bendix Aviation Corp) — Chem.& Eng.News.28.(18) p.1512. 1 May 1950.
Announcement of a direct reading humidity and temperature indicator, the "Hygrodial" coming off the production lines after field and laboratory tests. Humidity from 0 to 100% in steps of 10% on a 2½ inch scale.

423. —— — The Instrument Manual United Trade Press Ltd. pp.323-335. 1949.
Description and diagrams of various instruments. Reference Tables. Buyers Guide.

424. Behar, M. F. — Instruments, 3, 10-11, 1930.
HUMIDITY MEASURING INSTRUMENTS. Very thorough treatment.

425. Crise, G. W. — U.S.Pat.2,369,215 13/2/45.
HUMIDITY RESPONSIVE SWITCH. Depends upon the change in weight of an absorbant material with bimetallic strips to compensate for temperature change.

426. Crivelli, P. A. Refrigeration Jnl. 332 Jan. 1948 Bull.
Brit. Sci. Inst. R. A. 5. 243. 1950.

METHODS OF CALIBRATING AND MEASURING RELATIVE HUMIDITY. A detailed study of electrolytic hygrometers is given, followed by a comparison with hair hygrometers and a discussion of metallic powder hygrometers.

427. Gregory, H. S. Instrument Practice, 1947, 1, 367, 447.
August/October, 1947.

THE MEASUREMENT OF HUMIDITY. Types of hygrometer described are: chemical, dew point, wet-and-dry bulb, balanced temperature, hair, thermal, pressure difference, electrolytic, gravimetric, diffusion (Greinacher). The theory of the modes of operation is discussed.

428. Foskett, L.W., Foster, N.B. Bull.Amer.Meterol.Soc. 24 146-153 1943.
Sci.Abstr. 46A 247, 1943.

SPECTROSCOPIC HYGROMETER. A simple grating spectrophotometer is used with a tungsten filament lamp projector to measure precipitable water in the atmosphere. Use is made of the 1.380 mu water vapour absorption band and the 1.250 mu region for reference. Vacuum thermocouples and high sensitivity galvo. are used for energy measurement. Calibration tests were conducted over optical paths 1.5 - 52 m.

429. Glueckauf, E. Proc. Phys. Soc., 1947, 59, 344-365.

ABSORPTION HYGROMETERS: BEHAVIOUR AT LOW TEMPERATURES. A method has been developed for the calibration of hygrometers and for measuring their response at low temperatures. Investigations are reported on goldbeater's skin as a hygrometric element, and on the electrolytic hygrometer described by Dunmore (1939). Improvements concerning the response of the latter are suggested. A new optical hygrometer, based on the interference of light reflected by thin hygroscopic films is described in detail; its advantages are temperature-independent calibration and satisfactory response down to - 60°C.

430. Greinacher, H. Helv. Phys. Acta, 1944, 17, 437-454, via
J. Text Inst., 1946, 37, A165. April, 1946.

DIFFUSION HYGROMETER. The differences between the diffusion rates of air and water vapour through porous plates are used in a new diffusion hygrometer. Two glass vessels, each closed at one end with a porous plate, are connected at the other end to separate manometers or to the same manometer through a three-way tap. Air can pass freely through these plugs and the air pressure is the same inside and outside the vessels. Water vapour can pass less easily and a diffusion pressure is set up. One vessel contains water, and the pressure excess is proportional to the difference between the saturated vapour pressure and the partial vapour pressure in the outside air. The other vessel contains a drying medium, and the excess pressure is proportional to the partial vapour pressure only.

comparison with other instruments, the behaviour under various conditions, and the construction of an indicating instrument based on these principles is discussed. See also Schweiz. Bauztg. [illegible] 1946.

431. Greinacher, H. Engrs. Dig., 9, 63, 1948.
A NEW MOISTURE-METER. THE DIFFUSION HYGROMETER. A simple and reliable direct-reading hygrometer is based on the different rates of diffusion of water vapour and air through porous substances. The instrument consists of a glass tube containing a drying agent and with a porcelain plate of fine porous material fixed with putty over its top. Air is admitted to the tube through a stop-cock to allow the internal and external pressures to be equal. The air inside the tube is dried by the drying agent, so that the internal pressure is that of dry air while the external pressure consists of the partial pressures of air and water vapour. Various versions of this instrument are considered, and the method of determining the absolute humidity of air with it is described. (1 fig.)

432. Griffiths, E. Proc. Phys. Soc. 34 94-5. 1922.
HYGROMETRY. A bibliography of some 50 references, classified in seven sections:- (1) Apparatus and Methods for Maintaining definite humidity. (2) The wet and dry bulb hygrometer. (3) The hair hygrometer. (4) Thermal effect on cotton hygrometer. (5) Hot wire method. (6) Absorption hygrometers. (7) Miscellaneous hygrometers and tests. pp. 1-49: "Some modified forms of Hygrometer."

433. Griffiths, E. Food Investigation Board. Special Report No. 8. H.M.S.O. 1933. 70 pp.
THE MEASUREMENT OF HUMIDITY IN CLOSED SPACES. Methods of control and measurement, and the types of hygrometer are described. 100 classified references.

434. Lichtgarn, F. Instruments, 20, 336, 1947.
A NEW METHOD OF MEASURING RELATIVE HUMIDITY. A concise history of the various methods adopted in the past to measure relative humidity leads up to the method presented by the author, in which elements were made of powdered iron and chromium oxides mixed with clay and kaolin, moulded by hand and fired after drying at about 428°C. for 60 hr. Electrical connections were made by painting colloidal graphite on half-an-inch at each end of the element. One such element, 4 in. long and ⅛ in. square, was connected to the grid circuit of a specially designed vacuum valve voltmeter with a top grid connection tube and an input resistance of 40 megohms. Placed out of doors, it gave excellent response over extremely wide changes of humidity and at temperatures as low as - 20°C. Further experimental elements have been made with a linear response from 28 to 100% relative humidity. Difficulty is being experienced at present in measuring 100% relative humidity. (1 fig.)

435. Mahajan, L. D. Indian J.Phys. 18 293-302 1944 Phys. Abstr. A48 305-1945.

HYGROMETERS. TIME LAG AND HUMID FATIGUE. Results given for effect of humidity changes on various hygrometers including the author's optical hygrometer. This contains about 1% Calcium chloride, 9% plaster of Paris and 90% of small pieces of hair. The time lag depends upon construction, rate of air circulation and immediate past history. The Mahajan hygrometer has a time lag of 16 minutes, the lowest of those tested.

436. Mahajan, L. D. Indian J.Phys., 1946, 20, 214, via Bull.Brit. Sci.Instr.R.A., 1947, 2, 228. October, 1947.

THEORY, CONSTRUCTION, AND WORKING OF MAHAJAN'S HUMIMETER. A small portable direct-reading hygrometer is described. It consists essentially of a small spring balance indicating the weight of a sample of moisture-absorbing substance. Approximate error is 2 per cent.

437. Müller, M. F. Instruments 22(9) 798-9. Sept. 1949.

CHARACTERISTICS OF HAIR-ELEMENT HUMIDITY INSTRUMENTS. Behaviour of these instruments in comparison with accurate dew point hygrometers. All hair instruments, regardless of cost, have the following characteristics. 1. Lag behind actual conditions, and the true peaks and valleys are never reached. A fair average is obtained but there are plus and minus errors. 2. Creep with time, perhaps several months, periodic readjustment is necessary. Spot checks with accurate instruments are useless but a whole cycle must be gone through.

438. Okada, T., Tamura, M. Proc.Imp.Acad.Tokyo 16 141-3. 1940. Sci. Abstr. A43 663. 1940.

CONDENSATION HYGROMETER. Two copper vessels, one with dry air and the other with moist air are connected by a U. tube manometer, cooled and the pressure difference observed. R.H. corresponding, is based on a formula connecting the various data easily measured.

439/440. Spingler, K. Tonindustrie-Ztg v 60 n 69 Aug. 27 1936 p. 848-51.

HUMIDITY MEASUREMENT IN BRICK DRYERS. Humidity measurements in brick drying plants; various types of hair hygrometers, psychrometers and electric resistance thermometers and their applications discussed.

441. Wexler, A. Instruments 22(3) p.221 March 1949.

CALIBRATING HYGROMETERS BELOW THE FREEZING POINT. Describes a humidity test apparatus for calibrating other instruments.

442. —— U.S.Army Service Forces Quartermaster Corps, Climatic Research Lab. Rep. No. 186-C (PB-8252), 1945, via Packaging Abs., 1947, 4, 303. June, 1947.
MEASUREMENT OF RELATIVE HUMIDITY BY MEANS OF A THERMO-ELECTRIC PSYCHROMETER AND A DEW-POINT RECORDER. The psychrometer consists of two thermocouples, one wetted; it does not need air circulation, and is remote reading. The dew-point recorder automatically adjusts the temperature of a small mirror until fogging recurs; the mirror temperature and ambient temperature are recorded. It has been operated at temperatures down to -50°C.

443. Anon Iron Steel Engr., July 1946, 124.
CONTROL DEWPOINT RECORDER FOR GAS HUMIDITY. This instrument, designed by the General Electric Co., determines automatically and continuously the amount of moisture in a gas. The test gas is brought into contact with a metal mirror which is cooled or heated until a temperature at which dew is formed is attained. This temperature is recorded graphically by means of a photoelectric eye.

444. van der Akker, J.A., Wink, W.A. Science, 97. 494. 1943.
DEW POINT HYGROMETER. Manipulation. Application of a wetting agent to the surface, leaving an untreated patch, on which condensation appears in contrast to the treated surface. A difference of reflectance of 1.5% can be detected.

445. Brown Bouveri & Co. B.P. 551,989, 1943.
IMPROVED DEWPOINT HYGROMETER. The temperature of the dew point devices is effected through radiation receiving devices.

446. Clifford, G. I. Air Control Installations Ltd. B.P. 611,730 11.11.46. B.I. 548. July 1949.
DEW POINT INDICATOR. The method where dew deposited on a mirror is detected by a photoelectric cell is improved by reflecting from the first cooled mirror on to a second cooled mirror before passing the light to the P.E. cell.

447. Farnsworth Television & Radio Corporation Brit.Pat., 591, 542, 21/8/47.
MOISTURE INDICATOR. Gas is introduced into a transparent envelope in which a metallic member is supported. When heated to a predetermined temperature the metallic member changes its external appearance in proportion to the amount of moisture surrounding it. (2 figs.)

448. Flosdorf, E. W. Chem. Eng. Progr. 43(7) p. 370. 1947.
LOW TEMPERATURE HYGROMETER. Diagrams. (1) High pressure instrument (mirror) as in U.S. Bureau of mines model R.I. 3399. (2) Low pressure Laboratory instrument. The Gas impinging on the mirror surface of a tube containing Acetone and solid CO_2.

449. Moss, E. B. Proc.Phys.Soc.(London) 46, 450-8(1934) May 1.
AN APPARATUS FOR THE DETERMINATION OF THE DEW POINT. The paper describes an optical system which, using diffraction by the dew droplets on a mirror, aids greatly the visual detection of dew formation. The system may be made automatic by the use of a photoelectric cell.

450. Stock, S. S. Gen.Elect.Review 52(4) 42-45.1949.Bull. Br.Sci.Instr.Res.Assn.4 176 1949.
DEW POINT RECORDER. A thermocouple is attached to a metallic mirror, which can be heated or cooled and maintained at the dew point temperature of the gas.

Electrolytic Instruments

451. Anon Tech.News Bull.(U.S.Nat.Bur.Stand.), Feb.1948,vol.32,13-15.
MOISTURE DETERMINATION BY ELECTROLYTIC FILM. Describes improved method for measuring small amounts of water vapour in gases which depends essentially on the change in electrical resistance of an electrolytic film as it absorbs water vapour. It is very flexible in operation and is readily adapted to numerous applications, such as measuring the moisture permeability of membranes, detecting minute concentrations of combustible gas in air or of oxygen in combustible gas, determining water vapour in oxygen or in liquid CO_2, measuring the capacity of drying agents, determining the water content of organic liquids and solutions, and measuring relative humidity in small or comparatively inaccessible spaces under rapidly changing conditions.

452. Allen, A., Howe, W. H. U.S.Pat.,2,359,278,3/10/44.
APPARATUS FOR DETERMINING THE CONCENTRATION OF MOISTURE IN MATERIALS. A method of measuring the partial pressure or quantity of moisture present in an atmosphere, comprises the steps of supplying electrical energy to a medium having a preferential affinity for moisture, which is a discontinuous function of temperature, and having an electrical character capable of influencing the flow of electrical energy in the medium which is a function of the quantity of the moisture; a current is passed in the medium to a critical equilibrium temperature corresponding to the quantity of moisture in the atmosphere, and the temperature of the medium is measured as an indication of the partial pressure or quantity of moisture present.

453. Amer. Instr. Co. Paper Tr.Jnl.126(6) 46.5 Feb.1948.
MOISTURE MEASURING EQUIPMENT. Brochure on an electric hygrometer. An instrument having a quick response.

454. Amer. Instr. Co. Paper Ind. & Paper World 28 902. 1946. Packaging Abstract No.2719.1946, and No.1067 and 1947.

AN ELECTRIC HYGROMETER. The Aminco-Dunmore instrument for high precision humidity measurement and control possesses a sensing element claimed to be the speediest known. It gives reproducible readings throughout the entire standard dry-bulb temperature range of 40° to 120°F and R.H. range of 7% to 100%. Micro changes ± 0.5% R.H. are instantly sensed, indicated or recorded within the standard temperature range. Results are reproducible to 0.002 mg. water per litre and detns. take 2 to 5 mins. only.

455. Dunmore, F. W. J.Res.Natl.Bur.Stands.1939,701-714.

ELECTRIC HYGROMETER: CONSTRUCTION. An improved electric hygrometer is described. An aluminium tube, 1.11/16th inches long, wall thickness 0.01 in., is coated with polystyrene resin and wound with a bifilar winding comprising 20 turns per inch of No.38 Amer.W.G. bare palladium wire. This unit is coated with a thin film of partially hydrolyzed polyvinyl acetate with the addition of a small amount of lithium chloride, the amount depending on the humidity range to be covered. The electric resistance of the film between the two cells is then a function of humidity. Methods of construction, coating, ageing and using the units in both a-c and d-c circuits are given. A method is also provided for the measurement of relative humidities from 10-100 per cent. by using several units of different sensitivities in parallel, with resistors in series with each.

456. Evans, R.N., Davenport, J.E. Ind.Eng.Chem.Anal.Edn.1942, 14, 507-510.

ELECTRIC HYGROMETER. A modified form of electric hygrometer is described in which the coil consists of two spiral threads of platinum baked on glass. The hygroscopic film is put on by merely immersing the coil in an alcoholic solution of the desired salt, e.g. lithium chloride, and allowing the alcohol to evaporate. The relations between the water vapour and the resistance of the coil is obtained through a study of the behaviour of the coil in a mass of water vapour the pressure of which is varied by changing the volume with a mercury piston, in systems in which the humidity is controlled by saturated salt solutions, and in measurements of the formation of water from the explosion of a known volume of a hydrogen-oxygen mixture. The results are shown graphically and discussed. The conclusion is drawn that the resistance of the electric hygrometer, if without hysteresis, may be expected to follow the water vapour pressure in a regular manner except at a water vapour pressure below that of the saturated solution of the salt used as electrolyte. By selecting the desired saturated solution, the electric hygrometer or a device of similar principle could be adapted to the control of humidity in industrial operations. Because of hysteresis, there is little possibility that the electric hygrometer can be used for water in oil determinations where one is interested in the mass of water in a closed space and not the vapour pressure of water.

457. Inst. of Paper Chemistry Paper Tr.Jnl.116(24) 16-19 1943 117(1) 12-15 1943.
ELECTRIC SWORD HYGROMETER. A sword driven into packages etc. gives R.H. of the air by means of a cylindrical hygrometric element. Conductivity of a film of P.V. Acetate containing a little Lithium Chloride, protected by a coating of alundum powder, and a coarse cylindrical screen. Details of app., and calibration.

458. Hickes, W.F., Foxboro' Co. N.Y. Refrig.Engr.54 351-4. 388. 1947.
DEWCEL HYGROMETER. HUMIDITY MEASUREMENT BY A NEW SYSTEM. This is the Lithium Chloride hygrometer, where the Li Cl. solution is brought up to the temperature for equivalent vapour pressures; no refrigeration. Adaptable for long range indication, recording and control.

459. McCulloch, L. U.S.Pat., 2,381,299, 7/8/45.
HYGROMETER. The apparatus depends on the change in the electrical properties of beryllium fluoride with the humidity conditions.

460. Munch, R. H. Industr. Engng. Chem., Aug. 1948, vol. 40, 67A-68A.
INSTRUMENTATION. Operation and application of the Dewcel, one of the newer devices on the market for measuring dew point, is briefly discussed. The instrument functions by bringing a saturated solution of lithium chloride to such a temperature that the partial pressure of water of the solution is equal to the partial pressure of water around the Dewcel. Dew points below ordinary room temperature are measured without employing a cooling medium, and dew points ranging from - 16° to ± 160°F. may be determined within specified ambient temperature limits. Response is rapid, making the unit adaptable to automatic control applications.

461. Negretti, H.N., Negretti, P.E., Spencer-Gergory, H. B.P.533,381 (February 12th, 1941).
IMPROVEMENTS IN OR RELATING TO HUMIDITY-MEASURING DEVICES. The device comprises hygroscopic material, which absorbs quantitatively aqueous vapour according to the humidity of its environment and which is interposed between electrodes connected in an electric circuit associated with means for measuring the electrical resistance between the electrodes, which varies according to the amount of aqueous vapour absorbed by the hygroscopic material (e.g. calcium chloride) is incorporated in a piece of textile cellulosic material such as cotton fabric.

462. Peter Spence and Sons
IMPROVED CHEMICAL INDICATORS.

463. Weaver, E. R., Riley, R. Anal.Chem., 20, 216, 1948.

MEASUREMENT OF WATER IN GASES BY ELECTRICAL CONDUCTION IN A FILM OF HYGROSCOPIC MATERIAL. The electrical conductivity of a thin film of such a material as phosphoric acid changes over a wide range with changes in the concentration of water in the atmosphere with which it is in contact. By adjusting the pressures of a sample of gas of known and one of unknown composition, they can be made to have the same concentration of water, shown by equal resistances of the detecting film. Apparatus and procedures for determining water vapour under a variety of circumstances are described, and characteristics of the method and sources of error are discussed. The method has the general merits of simplicity of operation, speed, great sensitivity and wide range. Only small samples are needed, and few substances interfere. The following applications are described: determining water vapour in compressed oxygen, liquid carbon dioxide and "Freon"; measuring relative humidity in comparatively inaccessible or small spaces, especially under rapidly changing conditions; determining moisture in powdered solids and the capacity of drying agents; determining the water content of organic liquids and solutions by rapidly measuring its vapour pressure; measuring the permeability of membranes to water; and detecting minute concentrations of combustible gas in air or of oxygen in combustible gas. (23 figs., 2 tables.). See also J.Res. Nat.Bur.Stand.40 169-214. March 1948.

Electric and Thermo-Electric Instruments

464. Anon Power & Works Eng.41 341.1946. Packaging Abstr.No.1349, 1947.

MOISTURE CONTENT MEASUREMENT. The application of short wave electrical discharges to a wide range of substances is now commercialised by self contained equipment named Aquatector. Appropriate electrodes are designed, and one model is for incorporation in an automatic continuous process for recording or signalling.

465. Anon Modern Industry (Amer.) 15 June 1950 p. 117.

SENSITIVE HUMIDITY CONTROLLER. Plastic square disc (about 1"-1½" side on which gold leaf electrodes are imprinted. Moisture affects current between electrodes (it does not say how?) and amplified electronically to controller and recorder sensitive to 0.5% of derived setting. (Stated to be sensitive to half a teaspoon of water in a room full of air.)

465a. —— Chem.Age 64 1665.887.9/6/1951.

INSTRUMENTS FOR CHEMICAL PLANT. Includes a description with illustration of a Humidity transmitter by Elliott Bros., London, Ltd. The instrument incorporates two dry bulb resistance thermometers and one wet bulb. The psychrometric difference as air is continuously drawn over the "bulbs" can be recorded.

466. Davis, N. R. B.P.570,416.9/12/1943.
Sun Vic Controls
BI-METALS ELEMENT. HYGROMETRIC APPARATUS. 2 elements, from one of which water is evaporated. Precautionary measures.

467. Drytester, G.m.b.H. Riv.Tessile, 1947, 2, 213, via J.Text.Inst., 1947, 38, A594. December, 1947.
ELECTRICAL HYGROMETER. A diagram is shown of the "Humido control" electrical hygrometer, which operates on the capacity principle; claims are made relating to its advantages.

468. Gar, K. A. Zavodskaya Lab. 13 1152. 1947. Chem. Absts. 44 7. 1950. 10 Jan.
INSTALLATION FOR THE STABILISATION OF THE HUMIDITY AND TEMPERATURE OF THE AIR. The Temperature is controlled by a dry thermo-regulator and the moisture by another thermo-regulator wetted with water and set for the temperature corresponding to the derived relative humidity. The 2nd regulator controls an electric fan and vapour producer. The temperature is controlled within 0.5° and humidity within 3-5%.

469. Kobel, E. Schweiz.Arch.angew.Wiss.Tech., 1945, 11, 238, via Packaging Abs., 1946, 3, 620. September, 1946.
ELECTRICAL HUMIDITY METER. The instrument depends on the difference in the heat losses in wet and dry air. Heat loss is measured by change in potential difference across a resistance with constant current. Other sources of heat loss are summarised; but for maximum sensitivity the loss due to convection and conduction in the air should be much greater than that from other sources. The instrument is calibrated by means of air drawn over sulphuric acid solutions. It is claimed to be suitable for both works control and research purposes.

470. Negretti, H.N., Negretti, P.E., Spencer-Gregory, H. Brit.Pat., 587, 307, 1947, via J.Text.Inst., 1947, 38, A528. November, 1947.
ELECTRICAL "WET AND DRY BULB" HYGROMETER. The claim is for a hygrometer on the "wet and dry bulb" principle in which the "bulbs" are represented by thermo-junctions and current is applied to a heating wire around the wet junction to raise its temperature to that of the dry junction as indicated by a null reading on a galvanometer. The relative humidity is given by the applied heating current.

471. Richards, L. A. Proc.Iowa Acad.Sci., 1938, 45, 175. Exp. Sta.Rec., 1940, 82, 302.
WET THERMO-JUNCTIONS FOR MEASURING RELATIVE HUMIDITY. A preliminary report of methods for making thermocouples suitable for precise relative humidity measurements, e.g. on soils or other hygroscopic materials.

472. Roepke, R. R. J.Phys.Chem., 1942, 46, 359-366,

VAPOUR PRESSURE: THERMO-ELECTRIC MEASUREMENT. In order to demonstrate the sensitivity of the modified thermo-electric method (Baldes) of measuring vapour pressure, the vapour-pressure lowerings of 0.00226M and 0.01086M sodium chloride were compared with that of 0.0292M sucrose, four different thermocouple units being used. The author discusses the conditions under which the method must be used to obtain an accuracy comparable with the sensitivity.

473. Segsworth, R.S., Low, A.R. B.P.580,143 of 30/5/1944:28/8/1946.
J.Text Inst. 38 A35 1947.

ELECTRICAL HYGROMETER. A direct-reading electrical hygrometer comprises a thin broad 'filament' of electrically non-conducting material responsive to humidity changes (preferably a broad, thin tape of felted or fine-weave cellulosic material, e.g. "masking tape") means for supporting this obliquely and openly exposed to air currents, including carbon contact grips, hand operated means for impressing a d.c. surge voltage of known value, and means calibrated in terms of relative humidity for measuring the resistance of the "filament" to the surge voltage. Several hygrometers may be arranged to be operated from a central station where there is a selector switch.

474. Sisco, C. W. Instrumentation, July-Aug. 1947, 2, No. 6, 14-15; Index Aeronaut., Dec. 1947, 3, No. 12, 54.

MOISTURE CONTENT OF GASES RECORDED WITH NEW DEW POINT INSTRUMENT. A new instrument, the "Surface Combustion Dew Point Recorder", makes a continuous record of the humidity of air and other gases. It operates within a temperature range of approximately -40°F. to room temperature. A sensitive thermocouple and a "Brown Continuous Balance Electronic Potentiometer" are used in conjunction with the instrument. The method of operation and the applications are given.

475. Van Dilla et al U.S. Army Service Forces Q.M. Corps.
Climatic Res. Lab. Report No. 186C.
(PB-8252) 1945. Packaging Abstract No.
No. 1073. 1947.

THE MEASUREMENT OF R.H. BY A THERMO-ELECTRIC PSYCHROMETER AND A DEW POINT RECORDER. Two types of instrument over a wide range are discussed. The first is for R.H. above the ice point and consists of two thermocouples, one of which is wetted by a wick. It has the advantage of remote reading and does not require forced air movement. It also evaporates less water than the mercury in glass psychrometer. The other instrument is an electronic dew point recorder, using a mirror, for sub-zero temperatures.

476. Westinghouse Electric & Mnfg.Co. U.S.P. 2,316,624 1943.
GAS MOISTURE CONTENT DETECTION APPARATUS. The gas is conducted through a transparent envelope in which is a graduated heat-conductive tube containing a correspondingly graduated thermocouple one end of which is cooled.

Wet and Dry Bulb Instruments

477. Awbery, J.H., Griffiths, E. Proc.Phys.Soc.47, 684 - 1935.
AN INVESTIGATION OF THE WET AND DRY BULB HYGROMETER AT LOW TEMPERATURES.

478. Balls, W. L. Nature 152 389-90 1943.
WET BULB HYGROMETER. A wet and dry bulb system (laboratory) for precision hygrometry is described.

479. Brooks, D. B., Allen, H. H. J.Wash.Acad.Sci., 23 p.121(1933).
TWO-WET-BULB HYGROMETER.

480. Dexter, S. T.
(refers to salt solution wet bulb thermometer for storage tests). See under "Grain".

481. Grapez, J. B.P.531,042 (December 27th, 1940).
IMPROVEMENTS IN PSYCHROMETERS. Claims an improved direct-reading psychrometer, which comprises special arrangement of dry-and-wet-bulb thermometers, with mechanical means for actuating a rectilinear rod which can be aligned with the meniscuses formed by the 2 levels of the thermometer columns, so as to indicate on a graduated scale the corresponding hygrometric degree of the atmosphere. The device can be made specially suitable for a given range of hygrometer readings.

482. Griffiths, E. Cold.Stor., 1939, 42, 161(Abstr.). Ice Cold.Stor., 1939, 42, 118(Abstr.).
HUMIDITY MEASUREMENT AND CONTROL. A paper delivered at the Refrigeration Conference at Karlsruhe, July, 1939. Describes various forms of the ventilated wet-and-dry-bulb hygrometer. Uses of the dew-point, hair and chemical hygrometers and other methods for controlling humidity are dealt with.

483. Irwin, J. Finish 6(8) 23-4. Aug. 1949.
A METHOD FOR CHECKING WATER VAPOUR IN DRYING SYSTEMS. Apparatus for drawing exit gases past dry and wet bulb thermometers by means of an air injector. The expanded and cooled air from the injector thereafter serves to cool the sample of exit gas from 450°F down to 150°-180°F at which temperature the wet bulb will indicate a humidity up to 13% or 13 lbs. of water vapour per 100 lbs. of bone dry air.

484. Sherwood, T.K., Comings, W.W. Amer. Inst. Chem. Engrs. Meeting Dec. 1932.
AN EXPERIMENTAL STUDY OF THE WET BULB HYGROMETER.

485. Siebert, H. Gesundheitsing, 1940, 63, 100. Bull. int. Inst. Refrig., 1940, 21, 268.
A NEW HYGROMETER (transl. title). Describes a new hygrometer, the "Hygromat", in which wet-and-dry-bulb thermometers, aeration equipment and the psychrometric chart are enclosed in one shell. After setting 2 pointers, direct reading of the relative humidity is obtained. Various types of "Hygromat" are constructed for different purposes, e.g. for use in rooms and in the open air, for meteorological work or in a drying room.

486. Stucki, S. I. A. E. Schweiz, Bauztg., 1946, 128, 292, via J. Text. Inst., 1947, 38, A346. August, 1947.
ASPIRATION PSYCHROMETERS. The Assman and Haenni aspiration psychrometers are briefly considered and compared; neither instrument is considered really satisfactory. Inaccuracies arise from conduction to or from the thermometers, as a result of the air stream, from inadequate wetting of the wick, etc. Fifteen points to be observed when making humidity measurements include: ample time to reach equilibrium with the ambient temperature; an air speed of 2-4 m. per sec.; sufficient time for complete wetting of the wick; correct placing relative to surrounding objects; protection from radiation.

487. Warburton, F.L., Wool, R.A. Proc. 3rd Textile Teachers Conf. April 45. 6-15.
HUMIDITY AND REGAIN MEASUREMENT. Account of the use of the wet and dry bulb thermometer. Other methods of measurement and errors. Measurement of regain. Tables for wet and dry bulb thermometer.

488. Whipple, F. J. W. Proc. Phys. Soc. 45 307-9. 1933.
THE WET AND DRY BULB HYGROMETER. The relation to theory of the experimental researches of Awbery and Griffiths.

489. Williams, W. O. Science, 1942, 95, 283-284.
WET-AND-DRY-BULB HUMIDISTAT. A sensitive humidistat, the operation of which is controlled by the difference in temperature between ether-filled wet and dry bulbs, is described and shown in a diagram. The two bulbs are connected by a manometer tube and the difference in vapour pressures of the ether in the bulbs displaces a mercury column across platinum contacts sealed in the connecting tubing. Approximate adjustment for the desired humidity range is obtained by varying the amount of mercury for the desired humidity range is obtained by varying the amount of mercury in the manometer tube by adding or subtracting from a reserve supply stored in the bulbs. Final adjustment is made by swinging the instrument about a pivot. A sensitive relay is used, and a large reservoir is provided to supply the wick cup for the wet bulb with distilled water over an extended period. The

practical sensitivity of the control depends to a large extent upon the rate of change of humidity in the environment and air flow over the bulbs. Sling psychrometer readings indicate, however, that in a closed constant-temperature room, control has been obtained well within 1 per cent. relative humidity of a desired value.

INSTRUMENTS NOT HYGROMETRIC

490. Various Authors. Agric. & Mech. Coll. Texas Bull. 120. Oct. 1949. 99pp.
INSTRUMENTATION FOR THE PROCESS INDUSTRIES. 10 Papers given in the fourth annual short course. Includes Measurement and Control of Temperature by D. H. Fuller. Discussion of the various systems of control and circuit diagrams pp. 69-81.

491. Edit. Chemical Age 59 1535 11 Dec. 1948. Steam Engineer. 7pp. March 1950.
MOBILE TESTING UNIT. Illustrated pamphlet describing the mobile testing unit of the Ministry of Fuel and Power. Fully equipped with the necessary instruments to carry out complete heat balance tests of works boiler plant and process equipment. No description or details of instruments.

492. Anon Food Inds. 6(4) 159. 1934.
A portable electric apparatus developed by the Dried Fruit Association, California. The conductivity of the sample is measured.

493. Anon Amer. Gas J., Feb. 1946, 164, No. 2, 45.
RAPID HEAT CALCULATOR. A description is given of a rapid calculating device for measuring radiation for steam and hot water heating systems, consisting of a round dial with two concentric celluloid printed discs. The dial includes sizes of mains, returns, risers, radiator sizes and capacities, round and sectional boiler net ratings, chimney flue sizes and capacities with minimum and maximum heights and hot water and fuel oil tank sizes and capacities.

494. Brabender G.m.b.H., Duisburg O. T. S. Dept. Comm. U. S. A.
THERMAL MEASURING INSTRUMENTS, MOISTURE AND VISCOSITY CONTROL APPARATUS AND CLIMATIC CABINETS AND RELATED APPARATUS. 1937-1940. Microfilm \$ 6.50. Ph. \$ 23.75

495. Fox, L. L., Palmer, P. L., Whittaker, D. DSIR/4983/C. Feb. 1951. To be publ. J. Sci. Inst.
A COMPENSATING CIRCUIT FOR THE SIMMONS SHIELDED HOT-WIRE ANEMOMETER. Large errors in the measured air flow are reduced by injection of a

small E.M.F. into the thermo-couple circuit from the heater circuit.

496. Gregg, S. J.
HEAT OF SORPTION. See under Sorption.

497. Molloy, E. (Ed.) London: George Newnes, Ltd., 5/-; title in Engineering, 30 July 1948, vol. 166, 106.
ELECTRICAL MEASUREMENTS, SWITCHBOARD INSTRUMENTS, PORTABLE TESTING INSTRUMENTS, A.C. BRIDGE METHODS, VALVE VOLTMETERS, PYROMETRY, OSCILLOGRAPHY ETC.

498. Sasaki, Nobuji. Rev. of Sci. Instr. 21. (1) pp. 1-3.
Kyoto Univ. Japan Jan. 1950.
A NEW METHOD OF MEASURING SURFACE TEMPERATURE. Based on the brief contact of a thermocouple with the surface. If the thermocouple is at the same temperature as the surface, there is no deflection of the galvanometer. Free from radiation effects.

499. Poole, R. Heat. Vent. Engr., Apr. 1946, 19, 415-422.
AERODYNAMICS FOR THE HEATING AND VENTILATING ENGINEER. PART III. MEASUREMENT OF AIR FLOW. The main part of the paper is devoted to an illustrated description of a direct-reading air velocity meter suitable for industrial testing or laboratory research.

500. Rüb, F. Textil berichte 24 392-403 1943.
Chem. Abstr. 38 6138. 1944.
TEMPERATURE AND HUMIDITY MEASURING INSTRUMENTS. A discussion of the use of hair hygrometers, hygrographs and synchrometers, temperature measurements with mercury thermometers, recording mercury thermometers, thermographs, and electrical resistance thermometers.

501. Walter, L. Practical Engineering, 1948, 18, 386-388, 442-443, 470-471, 504-506.
THERMOMETERS AND PYROMETERS: INDUSTRIAL USES. An illustrated article dealing with the use of thermometers and pyrometers for industrial processes, their design, function and installation under the headings: The various types and method of choosing industrial thermometers; Actuating mechanisms for thermometers: pyrometers; Electrical resistance thermometers; and Function and installation of electrical thermometers.

MOISTURE DETERMINATION

General

502. ---- British Standards Institution (No.756-1939 34pp.).
BRITISH STANDARD SPECIFICATION FOR APPARATUS FOR THE DETERMINATION OF WATER BY DISTILLATION WITH AN IMMISCIBLE LIQUID. (SUPERSEDING B.S. 614-1936 AND B.S. 756-1937). The method of distillation with an immiscible liquid is used for the determination of water in a variety of substances, e.g., petroleum and petroleum products, tar and distillates, paints, foods, vegetable products, textile materials, coal and coal products, etc.

503. Bainbridge, J.R., Scanlan, F.G., Belyea, I. Fuel 28 88-90. Apr. 1949.
DETECTION OF MOISTURE IN BROWN COAL BY DISTILLATION. A new apparatus for removing moisture in 2-2½ hours, equally precise and shewing no bias as compared with the British Standard apparatus and is more pleasant to work with.

504. Baird Association Rayon, 1946, 27, 623.
WOOL: RAPID MOISTURE DETERMINATION. In a self-contained, forced draught drier, four individual chambers permit simultaneous drying of four samples of 400 g. each. Temperature is controlled to within 2°C., and rotary pumps force 13 cubic ft. of air per min. through the sample. Samples with 60 per cent. regain are dried in 30 min. The moisture-laden air is driven off through a vent at the top of the apparatus.

505. Brock, R. B. Chem. and Ind., 66, 299, 1947.
THE INFRA-RED DIRECT READING MOISTURE TESTER. Experiments with a number of materials on the rate at which moisture could be expelled by infra-red light showed that in most cases it could be driven out without raising the sample to boiling-point, and that the penetrative power of the beam was of considerable use. A moisture tester was developed consisting of a high quality balance with an air-damped system of plastic cylinders and a plastic piston machined on its outside diameter. The balance was an unequal arm with the pan support above the beam as a single rod passing through a heating chamber, working in conjunction with infra-red light with variable strength allowed for by a tapped transformer. The material determines the rate at which drying can take place, and with some organic materials vapours other than moisture appear to be driven off; furthermore, there is no certainty that water of crystallisation or water not "loosely" held will come away in the same proportions by oven drying and infra-red.

506. Bunzell, H. H. Cereal Chem. 12, 54-6, 1935 Jan.
THE BUNZELL-BECKER MOISTURE DETERMINATION APPARATUS. Description of laboratory weighing apparatus enclosed in glass (2 inverted desiccator bottoms) and evacuated. Determination takes 30-45 min.

507. Cherry, R. H. Anal. Chem. 20 958-62 Oct. 1948.
DETERMINATION OF WATER VAPOUR IN GASES. The application of thermal conductivity for determination of water vapour in gaseous mixtures is described. Application to air, nitrogen and oxygen.

508. Gallaway, W. S. Oil Gas Jnl. 47 279-288 Nov. 1948.
WATER DETERMINATION IN GASEOUS PROPANE BY INFRA-RED SPECTROSCOPY. Rapidly and accurately carried out in the region near 6 microns. An accuracy of 0.05 to 0.1 m.g of water to 1 litre of gas is easily realised.

509. Geddes, W. F. Cereal Chemistry 19 605-9. 1942.
PRECISION DETERMINATION OF MOISTURE IN FLOUR. The accuracy of vacuum and air-oven methods are discussed.

510. Grover C. & I. 365. 1946.
REVIEW OF PHYSICAL AND CHEMICAL TESTS FOR MOISTURE IN VARIOUS MATERIALS.

511. Iles, W. G., Sharman, C. F. J. Soc. Chem. Ind. 68(6) 174-5. June 1949.
Imp. Tobacco Co.
THE EFFECT OF VENTILATION IN MOISTURE TESTING OVENS. The steaming effect vitiates the determination. Investigation of 5 requirements using tobacco:- 1. Sacrifice of oven capacity to uniformity. 2. Control of rate of air flow. 3. Adequate preheating of air. 4. R.H. of incoming air should be constant and low. 5. Constant procedure for cooling the samples after test.

512. Marskell, W.G., Payner, J.E. Fuel, Mar.-Apr. 1947, 26, 49-50.
IMPROVED APPARATUS FOR DETERMINATION OF WATER IN OILS AND FUELS. A modified form of the Dean and Stark apparatus has been constructed, in which the mixed vapours from the distillation are carried to the top of a tube condenser and hence the vapour moves downwards. In this way the higher boiling point fraction condenses at the top of the condenser and washes down the lower boiling point liquid which condenses lower down the condenser tube. No ring of water is left adhering to the glass and no troublesome removal is required.

513. Mitchell, T. J. C. & I. No. 47. pp751-753. 25 Nov. 1950.
THE RATE OF EVAPORATION IN THE DETERMINATION OF WATER. Comparison of various containers shewed that the rate was higher for metal containers.

514. Meitzert, K. Getreide, Mehl, u Brot. 2. (5/6) 36. 1948. Food Sci. Abstr. 21 (1) 53 1949. Chem. Abstr. 43 3532. 1949.
NEW RESULTS OF INVESTIGATIONS INTO METHODS WITH DRYING CABINETS. Determinations by heating and by conductivity are affected by fineness of material etc. For meals, 130°F. for 1 hour is sufficient, but 150°F. is required for hard meals, macaroni meal etc. Electrical conductivity depends upon the ash and moisture content.

515. Oguri, S. J. Soc. Chem. Ind. 36, 504-613 (1933).
HYGROSCOPIC MOISTURE OF CELLULOSE XII. DETERMINATION OF HYGROSCOPIC MOISTURES OF VARIOUS PRODUCTS - CELLULOSE.

516. Pfister, R.J., Kerley, D.J. A.S.T.M. Bull. No. 127. 17-22. 1944.
FUEL GAS: WATER VAPOUR DETERMINATION. An Evelyn photoelectric colorimeter is used, and requires a sample of condensate frozen out at -70°C from a measured volume of gas to yield 0.25 grm of water, after warming to remove non-aqueous condensate. To the condensate 25 ml of water indicator solution (0.1% cobaltous bromide in butonol) are added and the transmission is read in the Evelyn calorimeter with 660 micro.mu. band filter. Calibrated graphs are then used.

517. Rammler, E. Arch. Warmewirt 13, 203-9 (1932) Aug.
METHODS OF MOISTURE DETERMINATION AND THEIR SUITABILITY FOR INVESTIGATION OF DRYERS. Review of various drying processes classified according to principles upon which they are based. Methods of moisture analysis and inspection.

518. Richards, L.A., Weaver, L.R. J. Amer. Soc. Agronomy, 35, 1002, 1943.
THE SORPTION-BLOCK SOIL MOISTURE METER AND HYSTERESIS EFFECTS RELATED TO ITS OPERATION. A porous ceramic block, if protected from evaporation, will come to moisture equilibrium with soil with which it is in contact. A description is given for a sorption-block soil moisture meter based on weighing the block while suspended in the soil, thus avoiding exposure to evaporation. Various tests made indicate that this type of apparatus can be used for measuring the condition and amount of moisture in soil. Data on the hysteresis effect for six soils are given. The occurrence of hysteresis in ceramic sorption blocks is noted, and this, being in phase with that of the soil, should improve their action for measuring soil moisture.

519. Sobolev, A. B.R.S. Note No. E220 Sept. 1950. D.S.I.R. 5176/C.
THE STEELYARD MOISTURE METER. A simple method for measuring the moisture of aggregates and sand. The principle is that of water displacement after immersion of a known weight, (calibrated to dry weight) and observation of the water displaced as an overflow from a can balanced on a steel yard.

520. Ward, A. L. J. Inst. Fuel. pp. 1-4 Jan. 1951.
METHODS OF ESTIMATING MOISTURE. The significance of moisture content. Objects of determination, sampling. Survey of available methods.

Electrical Methods

521. —— Paper Trade Jnl. 126(25) p. 62. 17/6/1948.
THWING ALBERT ELECTRONIC CO. MOISTURE TESTER. Battery operated probe. 4% to 50% moisture can be measured.

522. —— Invention, 1940, 4, No. 6, 18.
An electric hygrometer for the determination of the moisture content in raw materials such as coal, has been produced by Brabender G.m.b.H. of Duisburg, Germany. The hygrometer includes a high-frequency generator, in the circuit of which is connected an external winding about a pipe through which the material to be tested is passed. As the strength of the current passing through the coil depends on the amount of moisture in the interior of the coil, an accurate indication of the moisture present in the material under test can be determined by measuring the current changes. A suitable graphical recording instrument is provided to record these values. A second high-frequency circuit, which may be regulated by hand, is built into the registering apparatus for compensation of the current in case of unusual or non-indicative conditions. A feature of the apparatus is that it determines and records the moisture content of the sample independently of the amount of moisture at any given point in the sample.

523. Anon. Moisture Register Co Textile World, 1948, 98, No. 6, 144.
HIGH-FREQUENCY MOISTURE TESTER. A photograph is shown of an instrument that measures average moisture content up to a depth of 3 inches over a range of 0 to 15 per cent.; it is suitable for wool (loose, tops, skeins and blankets) and bulk cotton.

524. Anon. Elec. Review 136. 619-620. 1945.
ELECTRICAL MOISTURE METER A report is given of a discussion of an electrical moisture meter (National Physical Laboratory) for the testing of seeds and grain, food products, straw fibre, etc. In this instrument a constant alternating current is applied to a sample of the material contained in a small vessel that may be regarded as a fixed air condenser, or in some instances as a conductive cell. The current passing through the sample is measured by a sensitive thermionic ammeter of special construction, which can be adjusted to indicate either the capacitance, proportional to the dielectric constant of the sample, or the conductance, proportional to its AC conductivity; alternatively some function of both the former values may be indicated. The current selected is that which shows the most favourable variation with moisture content. Reference is made to other moisture meters based on similar principles.

525. Aronovski & Sutcliffe, Paper Tr.Jnl.5.1.1948 126 3.
Wilson
MOISTURE OF STRAW IN BALES. Two electrode instruments for testing resistance. 1. Delm horst Moisture Meter, 4 pp. 2. Circuits 2 pp.

526. Babb, A. T. S. Soc.Public Analysts Meeting 1st Jan.1950.
A RADIO FREQUENCY MOISTURE METER FOR ROUTINE CONTROL. (Based on experiments with egg and chicory.) It is based on a change in frequency by the material in a condenser. See Analyst. 76 Jan.51.

527. Baver, L. D., Shaw, B. T. U.S.Pat.2,362,344,7/11/44.
APPARATUS FOR MEASURING MOISTURE. In an apparatus for determining moisture by measuring thermal conductivity a Wheatstone bridge circuit has a heating coil in one leg adapted to be inserted into the test material, two other legs of the bridge circuit being formed entirely of fixed resistors, with a variable resistance in the fourth leg of the bridge. A microammeter is connected across the legs; a circuit having an ammeter, battery and variable resistance therein, a switch for connecting said circuit to the Wheatstone bridge circuit, a supplementary balancing resistance, a switch for selectively connecting the supplementary resistance into or out of series with the current applying circuit, whereby the bridge may be balanced with a small current when the supplementary resistance is connected in series with the current applying circuit.

528. Colloid Equipt. Co., Text.Mnfr.67 p.146 Apr.1941.
50 Church St., N.Y.
DELMHORST MOISTURE METER. Electrodes are pressed into the material, and the % moisture read on a dial. Self contained. Accurate to 1% over 8 to 24%.

529. Colman, E.A., Hendrix, T.M. Soil Sci.67 425-438.1949.
FIBREGLASS ELECTRICAL SOIL-MOISTURE INSTRUMENT. Comprises an electrical resistance, and a thermally sensitive element, (a thermistor) suitably enclosed for staying in the ground.

530. Faber Instrument Co. Rayon Textile Monthly 26 487 1945.
MOISTURE METER FOR CURVED PACKAGES. Model K-2 can test a wide variety of materials having curved, rough or flat surfaces. Electrode maintains contact whatever the contour.

531. Ferranti Ltd. Tootal Broadhurst B.P.591,147 of 19/9/1944:
Lee Co., Ltd., Taylor, M.K., Neild, L. C. 8/8/1947.
DIELECTRIC-LOSS (MOISTURE CONTENT) MEASURING APPARATUS. The invention relates generally to apparatus for measuring a physical state of a material that affects dielectric loss, but is described as applied to the measurement of the moisture content of a textile fabric. It comprises (1) a condenser between the plates of which the material is disposed, the condenser being incorporated in the tuned circuit of an

amplifier, (2) a tunable oscillator circuit for feeding the amplifier, (3) automatic means in one of the circuits for the cyclic and repeated variation of the tuning through a frequency band, including the resonant frequencies from all likely changes in the particular physical state, and (4) means for deriving the value of the resonant amplitude of oscillation in the tuned circuit at different degrees of amplitude occasioned by the different dielectric losses.

532. Marconi Instr. Ltd., Bartley, W.B. B.P.569,889 26/7/1943.
HIGH FREQUENCY HEATING MOISTURE CONTENT DETERMINING APPARATUS. For a porous, granulated or particulate substance. Means for applying energy are discussed. The power loss to the substance decreases as the moisture is driven off and the stages of drying can be followed thereby.

533. Boeke, J. Phillips Tech. Rev., 1947, 9, 13, via Chem. Trade J., 1947, 121, 54. 11 July, 1947.
RAPID MOISTURE DETERMINATION. The water in the material to be tested is extracted by means of an acetone solution of oxalic acid in a closed vessel: the change in conductivity of the solution is related to the amount of water taken up, by calibration curves. Methyl and ethyl alcohols may be used instead of acetone.

534. Marconi Inst. Co. Bartley, W. B., Brit. Pat. 592, 450, 18/9/47.
May, P. C.
APPARATUS FOR DETERMINING THE MOISTURE CONTENT OF MATERIALS. Provided the material is below "saturation" point, the moisture content of many vegetable and mineral substances can be determined by the measurement of an electrical property, the success of the measurement depending upon its reproducibility. This patent is an apparatus for determining the moisture content of materials by the measurement of conductance, admittance, or susceptance of a mixture of the substance of the material and air. A chamber, which accommodates the material, consists of a conductive tubular wall closed at its base by an insulating closure. On the inside of this closure a guard strip is placed between two electrodes and conductively connected to the wall. A spring-loaded upper closure applies a predetermined mechanical pressure. (3 figs.)

535. Smith, A. L. U.S. Pat. 2,437,134, 2/3/48.
ELECTRODE ASSEMBLY FOR MOISTURE METERS. An electrode assembly for measuring soil moisture consists of a tubular composite shaft at the lower end of which is a pointed metal electrode. A metal tube extends the length of the shaft, is insulated from the electrode and has a constricted portion just above it. Outside this portion is an insulating sleeve of diameter corresponding to that of the electrode, and the surface of which merges with that of the lower end of the electrode. A metal section, forming part of the tube just above the

insulating sleeve, has a slightly larger diameter than that of the sleeve and of the pointed electrode; its surface tapers at the lower end and merges into the surface of the sleeve. The tapered portion acts as a second electrode.

536. Toplis, L. G. Elect. Rev., 161, 523, 1947.
ELECTRICAL MOISTURE METER. The N.P.L. meter was designed principally to give an indication of the moisture content of cereals, seed, and food powders. In materials such as butter, however, there is always a certain amount of free water present, and such moisture has a high conductance value in an electrical circuit that is out of all proportion to the true moisture content. For this reason a test electrode has been designed in the form of a shallow dish of dielectric material fitted into a rectangular framework, which itself carries the electrode plates: these in turn are coupled to the instrument. The butter is carefully packed in the dish and inserted in the frame. There is thus no metallic contact between the substance and the electrode plates themselves, and therefore the current reading obtained on the indicator is entirely due to capacitance. (3 figs.).

Fischer Method

537. Cornish, G. R. Plastics 10 99. Feb. 1946.
DETERMINATION OF MOISTURE IN PLASTIC MOULDING POWDERS by the KARL FISCHER METHOD. A description of the reaction and method is given together with the precautions necessary at each stage.

538. Jones, A. G. Soc. Publ. Analysts. Meeting 1 Feb. 1950.
A REVIEW OF SOME DEVELOPMENTS IN THE USE OF THE KARL FISCHER REAGENT.

539. McComb, Elizabeth A. Anal. Chem., 1948, 20, 1219-1222.
PROTEIN MATERIALS: DETERMINATION OF MOISTURE. The rapid volumetric method, using the Fischer reagent, for the determination of moisture has been applied to protein materials such as chicken feathers, dried egg white, gelatin, hog hair, gum gluten, soybean protein, and zein. Conditions necessary to obtain optimum values are described, and typical results obtained on these materials by the Fischer method, three oven methods, and the vacuum drying method (over magnesium perchlorate) are presented. The Fischer method gives satisfactory results.

540. Mitchell, J., Smith, D. M., du Pont Co. Aquametry Interscience Publishers Inc., New York 1948.
THE APPLICATION OF THE KARL FISCHER REAGENT.

541. Seaman, W., McComas, W. H., Allen, G. A. Anal. Chem. 1949, 21, 510-512.
WATER: DETERMINATION BY KARL FISCHER REAGENT. A modification is proposed of the Karl Fischer method for the determination of water.

Instead of using a single solution containing sulphur dioxide, pyridine, methanol, and iodine, two solutions are used; one containing pyridine, sulphur dioxide, and methanol for dissolving or suspending the sample and the other containing iodine and methanol for titration. The reaction goes stoichometrically according to the equation; $H_2O + SO_2 + I_2 = SO_3 + 2HI$ without side reactions but in practice it is convenient to standardise the solution empirically. This modified method avoids the decomposition that occurs with the usual Fischer reagent. Experimental data are presented. It is shown that the precision with the new method is of the same order of magnitude as for the original method.

542. Shroeder, C.W., Nair, J.H., Anal.Chem.20 452-5.1948.
Continental Foods Inc. Hoboken, N.J.
MOISTURE IN DRIED FOOD STUFFS. The Karl Fischer method is the most reliable.

543. Turner, W. P. Food Industries 18 502-5. 4/1946.
WATER CONTENT BY FISCHER METHOD.

544. Wernimont, Grant, Ind.Eng.Chem.Anal.Edn.15 272-4.1943.
Hopkinson

Gas Evolution Methods

545. Aubone, E. Bol.informaciones petroleras (Buenos Aires) 1944, 21, No. 236, 15-18; Chem.Abst. 1944, 38, 6513.
METHOD OF DETERMINING CONTENT OF WATER IN ALCOHOLS AND MIXTURES OF ALCOHOL WITH NAPHTHA (FUELS). Using various alc.-hydrocarbon mixtures, A. made tests of the method of H_2O determination with CaC_2 and measuring the volume of C_2H_2 generated. Data show the method as satisfactory for small samples, and may also be used with other alcohols than EtOH.

546. Baker, B.T., McNevin, W.M. Anal.Chem.22(2)p.364 15 Feb.1950.
LITHIUM ALUMINIUM HYDRIDE AS A REAGENT FOR DETERMINATION OF WATER. The present technique is suitable for approximate estimations of small quantities (say 0.1%) of water.in hydrocarbon, ether and other non-reactive materials. $LiAlH_4 + 4H_2O = LiOH + Al(OH)_3 + 4H_2$ but the amphoteric property of $Al(OH)_3$ may produce a further reaction to $Li\ H(OH)_2$.

547. Delmhorst, W. J. U.S.Pat., 2,359,831, 10/10/44.
APPARATUS FOR TESTING MOISTURE CONTENT IN GRANULAR MATERIAL. Apparatus for testing the moisture content in granular material comprises a receptacle in which a sample of the granular material may be placed, a container attached to a portion of, and disposed within this receptacle, in which calcium carbide may be placed. The container has an opening covered by a wire screen to permit the

calcium carbide to be shaken into the receptacle to mix with the sample of granular material; acetylene formed by the reaction may freely escape from the receptacle by passing through the container.

548. Graefe, E. Petroleum 1 813-17. 1906.
DETERMINATION OF MOISTURE BY CALCIUM CARBIDE.

549. Pipparelli, E., Simonetti, A. Ann. Chim. Applicata, 1943, 33, 3-8; Chem. Abst. 1944, 38, 5470.
METHOD FOR THE DETERMINATION OF MOISTURE IN GASES. In determining moisture in gases by the use of Mg_3N_2 an error can be caused by the formation of some $Mg(OH)_2$. This can be prevented if the reaction tube is kept at 100^0. The presence of small quantities of CO_2 in the gas does not interfere. When larger quantities of CO_2 and water are present, $(NH_4)_2\,CO_3$ is formed, part of which remains in the reaction tube.

550. Roth, F., Schnoor, A. Brannstoff-Chem. 1941, 22, 89-90.
METHOD FOR DETERMINING MOISTURE IN SOLID MATERIALS. A regulated current of inert gas, e.g. N_2, after passing through the sample heated to $80\text{-}90^0$, enters a tube containing Mg_3N_2. The NH_3 evolved by the reaction $Mg_3N_2 + 6H_2O = 2NH_3 + 3\,Mg(OH)_2$ is absorbed in excess N/20 HCl and the unused HCl subsequently determined. The apparatus is illustrated. The method is rapid (25-30 min.) and applicable to all materials, e.g., coal, coke, and tobacco, except those which evolve NH_3 on heating.

Hygrometric Methods

551. ---- Br. Std. Specif. 1051: 1942.
MOISTURE IN RELATION TO TEXTILE MATERIALS. A method is provided for determination of moisture in textile materials, including definitions, examples of calculations, determinations of R.H. by ventilated wet and dry bulb or by sling hygrometer. Standards of regain for various fibres are given.

552. Balls, W. L. J. Text. Inst. 40 (11) T759-766 Nov. 1949.
AN AIR TEST FOR MOISTURE IN COTTON. The R.H. of air in equilibrium with the material (cotton) is measured and this value compared with a predetermined curve. Illustr. diagram and curve.

553. Burdick, C.L., Perrin, J. B.P. 517,796 of 29/9/1938: 8/2/1940. (See
London also Textile Mercury and Argus, 1940, 102, 156.
FIBROUS MATERIAL MOISTURE CONTENT DETERMINATION APPARATUS.
A method of determining the moisture content of grain, paper, fabrics and other substances having air in the composition of their bulk or within their corporate interstices comprises withdrawing air from the substance under test and passing it over dry and wet bulb thermometers so that the difference in readings of the two thermometers gives a

measure of the humidity of the air and thus of the moisture content of the substance from which the air was withdrawn.

554. Money, R. W. Soc. Publ. Analysts Meeting, 1st Feb. 1950
MOISTURE DETERMINATION OF GRANULATED PULVERISED OR MILLED FOOD MATERIALS SUCH AS SUGAR PRODUCTS.

SORPTION

General

555. ---- Ind. Eng. Chem. p. 19, Jan. 1948
REFERENCES ON WATER ABSORPTION. By Soils, silica gel, cellophane, proteins, penicillin, alum, soaps, leather, polymers, titania gel starches.

556. Anon Chem. Eng. News. 28(10) p. 801, 6.3.1950
J. F. Pritchard & Co., Dual absorber type A Hydryer for continuous drying of instrument air to-40°F dew point, by a split stream from the entering air or gas. The method of operation is not made clear.

557. Amero, R. C., Moore, J. W., Capell, R. G. Chem. Eng. Progr. 43(7), T. 349-370, 1947
DESIGN AND USE OF ABSORPTIVE DRYING UNITS. Steps involved in designing a drying unit, with special attention to method of calculating pressure drop. Regeneration is discussed.
Table 1. Typical Operations using Granular Desiccants.
Table 2. Comparison of drying agents and dehydration processes. About 22 reagents. Table 3. Drying costs.
Table 4. Variables affecting "Fluorite" desiccant performance.
Table 5. Relative drying efficiency of agents. Numerous data curves mainly on fluorite desiccant, and data concerning the drying of natural gas, 25 diagrams, 126 References.

558. Anderegg, F. O. B.P. 573,880/1945
DEHUMIDIFYING AIR AND GASES. Dehumidifying apparatus comprising a wall formed of a hygroscopic, moisture-pervious substance, over one face of which wall (e.g. the outer face) gas to be dehumidified is adapted to be passed, and means for passing heated gas over and in direct contact with the opposite (e.g. inner) face of the wall for removing therefrom moisture absorbed from the gas to be dehumidified.

559. Ansul Chem. Co. Tech. Service Bull. 1949
REFRIGERANT DRYERS. The characteristics of the refrigerants, methyl chloride, sulphur dioxide, Freon, their corrosive behaviour etc. when moist, and their behaviour with solid chemical and absorption drying agents. Experimental results are given.

560. Bangham, D. H. Nature 30/12/1944, 154, 837/8

THERMODYNAMICS OF SORPTION ISOTHERMS: THE HYSTERESIS LOOP IN CAPILLARY CONDENSATION. For two-component systems comprising one component of large or unknown molecular weight, a criterion is suggested for deciding whether the second component is or is not adsorbed as a film (as opposed to being dissolved, or condensed as liquid phase in capillary interspaces). A thermodynamic argument is advanced to show that "sorption hysteresis" is a necessary concomitant of capillary condensation; also that the wetting energy $\gamma \cos \theta$ (where γ = surface tension of liquid and θ the equilibrium angle of contact) is not constant, as invariably assumed, but is a function of the pressure.

561. Bocher, G. Chim. et Industr. 58, 31-5, 1947, B.I. 546, July, 1949

DESICCATION. Efficiencies of various sorbents, continuous action and regeneration. Efficiency = 1/R.H.

562. Bond, R. L., Griffith, M. Farad. Soc. Discussions. No. 3. p. [illegible]. 1948
Maggs, F. A. P.

SOME PROPERTIES OF WATER ABSORBED IN THE CAPILLARY STRUCTURE OF COAL. Important researches by B.C.U.R.A. concern the relation between the water in bulk and that adsorbed on coal, There is no evidence of a sharp freezing point when coal saturated with water vapour is cooled, thus capillary condensed water does not possess the properties of water in bulk. The heat of wetting with methyl alcohol indicates that no fresh surface is produced on grinding, until smaller than 240 B.S. mesh. Thus fine grinding does not necessarily increase the amount of surface.

563. Borgen, K. A. Dansk. Tids. Farm. 7, 61-71 (1933)

MOISTURE-ABSORBING MATERIALS AND THE RATE OF EVAPORATION OF WATER. The rates of evaporation from a H_2O surface and absorption in a drying agent follow the relation $M = (K_V 760 . O_V . K_S 760 . O_S / K_V 760 . O_V + K_S 760 . O_S)(760/b) eT$, where M = wt, of H_2O in mg., $K_V 760$ and $K_S 760$ are constant characteristics for H_2O and H_2SO_4, O_V and O_S are areas of H_2O and H_2SO_4 in sq. cm., b is the total pressure in mm. of the air and H_2O vapor in the desiccator and T the time in hrs. If the air is stirred the consts. are higher.

564. Power, J. H. U.S. Bur. Standards-J. Research v 12 n 2 Feb. 1934 p. 241-8

COMPARATIVE EFFICIENCIES OF VARIOUS DEHYDRATING AGENTS USED FOR DRYING GASES (SURVEY OF COMMERCIAL DRYING AGENTS).

565. Bradley, H. Nature 120, 3011, 1927. J.I.S.L.T.C. XIII 2/1929

Absorption results are represented by the formula $S = \frac{a p T/273 x}{1 - b p T/273 x}$

where S = substance taken up
p = pressure of substance at equilibrium e.g. % R.H.
T = absolute temperature
x = an integer (2 or multiple for water)
a and b = constants with respect to s and p and vary with T.

566. Caillaud, J., Beaufils, J. Chimie & Industrie v 35 n 6 June 1936 p. 1280-92
TESTING OF SILICA GEL AND OTHER DEHYDRATING AGENTS; method of testing to determine properties of silica gel in relation to drying of gases; only hygroscopic properties considered; modifications in these tests in order that they may be applied to other drying agents indicated.

567. SORPTION OF MOISTURE
See under Textiles - P. W. Carlene
see under Agriculture - S. T. Dexter
J. W. Creighton

568. Chilton, Colburn Ind. Eng. Chem. 26, 1183, 1934
MASS TRANSFER (ABSORPTION) COEFFICIENTS.

569. Danby, C. J., Davoud, J. G., Everett, D. H., Hinshelwood, C. N., Lodge, R. M. J. Chem. Soc., 1946, 918-934
GRANULAR GAS ABSORBENTS: KINETICS OF ABSORPTION FROM AN AIR STREAM. A theoretical treatment is given of the kinetics of the removal of a gas from an air stream by passage through a column of granular solid. Various relations are determined for typical systems and compared with those predicted theoretically. These relations include; the escaping concentration as a function of time, column length, flow-rate and initial concentration; the distribution of gas or reaction product in the column; and the influence of granule size. The independent parts played by capacity factors and rate factors are shown. shown.

570. Dickel, G. F.I.A.T. Review of German Science. Physical Chemistry 199-204, 1948. (In German)
ADSORPTION AND DESORPTION. Results of German investigations into the mechanism of adsorption and desorption phenomena are summarised. 35 References.

571. Gregg, S. J. J. Chem. Soc. 561-7, 1946
ELECTRIC SORPTION BALANCE and CALORIMETER. Sensitivity is independent of total load, which may be 10-20 grm., and is about .003 grm. Instrument is suitable for measuring various phenomena. Heat of sorption is measured by a thermo electric device incorporated, provided pressure of gas is greater than about 1 m.m. Mercury.

Results on activated alumina agree with those calculated by means of the Clausius Clapeyren equation from heat of wetting measurements. For the range 0.10 to 0.30 gr. of water per gr. alumina, the differential heat of adsorption lies within [illegible] of the latent heat of condensation.

572. Gregg, S. J., Maggs, F. A. P. Trans. Farad. Soc. 44(3)(303), 123-136, 1948
DETECTION OF CHANGES OF STATE IN FILMS ADSORBED AT GAS-SOLID INTERFACE. Published evidence for occurrence of phase-transformations in adsorbed films on solids, and for the existence of phases resembling the gaseous, liquid expanded and liquid condensed phases of films on water is cited. Methods of calculation from adsorption isotherms are given.

573. Guthrie, J. C. J. Text. Inst. Aug. 1949, 40(8), T.489-T.504
THE INTEGRAL AND DIFFERENTIAL HEATS OF SORPTION OF WATER BY CELLULOSE. Integral Heat of Sorption = Heat when completely wetted out. Differential heat of Sorption = Heat of Sorption of 1 gram of Water by an infinite mass of material. Experimental results are expressed in curves and in 4 Tables. Concludes that the water absorbing regions are similar for all types of cellulose, as shewn by the figures for both Heats of Sorption. Other conclusions regarding entropy change, stretching. Heats have been evaluated for all types of cellulose.

574. Hahn Mikrochemie, 20, 239, 1936
NEW PRINCIPLE FOR THE ABSORPTION OF GASES AND VAPOURS.

575. Harkins, W. D., Jura, G. J. Amer. Chem. Soc.: 66, 919, 1944
SURFACE OF SOLIDS. X. EXTENSION OF THE ATTRACTIVE ENERGY OF A SOLID INTO AN ADJACENT LIQUID OR FILM, THE DECREASE OF ENERGY WITH DISTANCE, AND THE THICKNESS OF FILMS. Almost all of the films adsorbed on the surfaces of non-porous solids, which have been investigated thus far, are highly polymolecular at vapour pressure very slightly below saturation. For the first time, a determination has been made of the effect of distance on the intermolecular attraction (in energy units) between a solid and an adjacent liquid or adsorbed film. This energy of interaction is found to suffer a decay which is essentially an exponential function of the distance. Measurements were made of the energy of vaporisation of liquid films on TiO_2. The results obtained are contrary to Langmuir's theory of the general occurrence of monomolecular adsorption at vapour pressures moderately close to saturation. They also show that the combined monolayer plus capillary condensation theory, upheld by a large number of the workers in this field, is incorrect. They do not show that monomolecular adsorption cannot occur, nor are they in opposition to the idea that capillary condensation may occur in porous solids. They do show that adsorbed films on plane surfaces commonly attain greater thicknesses than in porous solids. However, this should not be the case for water on hydrophobic solids. The theory of adsorption favoured by these results is in agreement with the general picture indicated by the multimolecular theory of Brunauer, Emmett, and Teller. However, the incorrectness of one of the primary assumptions in that more simple theory is pointed out: that the energy

of vaporisation of the second adsorbed layer is not greater than the energy of vaporisation of the liquid. Evidence is presented which indicates that capillary condensation does not play any significant role in the sorption with a crystalline powder of the type used in this work.

576. Hougen, O. A., Marshall, W. R. Chem. Eng. Progr. 43(4), 197-208, April 1947
ADSORPTION FROM A FLUID STREAM FLOWING THROUGH A STATIONARY GRANULAR BED. Methods are developed for calculating the time-position-temperature concentration conditions in both gas and solid during the adsorption of dilute gases flowing through granular beds. Mathematical treatment. Curves of rate of composition change. The methods may prove useful in analysing the last stages of drying deep beds by through circulation techniques.

577. Howard, W. J. Text. Inst. 39, T.351-367, 1948 Chem. Abstr. 43(3), 10.2.49
HEAT OF SORPTION OF WATER BY CELLULOSE. Method of Determination.

578. Ledoux, E. Chem. Publ. Co. Brooklyn, N.Y. 1945
VAPOUR ADSORPTION. INDUSTRIAL APPLICATIONS, 360 pp.

579. Ledoux, E. Chem. Eng. 53, 109-10, Sept. 1946
CONTINUOUS DRYING OF ADSORBENT MATERIALS.

580. Loisy, R. Bull. Soc. Chim. 1941., 8, 583-587 (through Chem. Abstr., 1942, 36, 1535^{6})
DRYING AGENTS: WATER ABSORPTION RATES. The rate of water absorption from a current of air 9 per cent. or 90 per cent. R.H. was determined for calcium chloride, charcoal impregnated with calcium chloride, two silica gels, and pumice or silica gel impregnated with sulphuric acid. The falling off of the rate with time was more marked at the lower humidity. Silica gel containing sulphuric acid was the fastest absorbent.

581. Mantell Chem. Met. Eng. 38, 232, 1931
PROGRESS IN ABSORPTION AND ADSORBENTS.

582. Othmer and Josefowitz Ind. Eng. Chem. 1948 40, 723-5 B.III.436, Sept. 1948
CORRELATING ADSORBTION DATA FOR CHEM. ENGG. CALCULATIONS.

583. Perry, J. H., Duus, H. C. Chem. Met. Eng. 41(2), 74-77, Feb. 1934
DRYING GASES BY ABSORPTION. Gives details of the drying characteristics of various solids and liquids. The data for moisture relations of various solids are given in 4 tables.

584. Phillip, J. C. Ind. Chem. 5. 534, 12/1929 Conf. of Chem. Engrs. 5/12/1929

REVERSIBILITY OF THE ADSORPTION PROCESS AND THE THICKNESS OF THE ADSORPTION LAYER. Attempted explanation of the hysteresis phenomena.

585. Ramet, A. Chim. et Industr., Techn., 1944, 64-7

USE OF ADSORPTION IN THE PURIFICATION AND DEHYDRATION OF GASES. The general theory of adsorption of gases is briefly discussed and the various adsorbents e.g. active carbons, silica gel, and various combinations, in use for purification and dehydration are reviewed. The applications of adsorption e.g. separation of rare gases, dehydration of air, removal of benzole and sulphur compounds from illuminating gas, purification of CO_2 etc., are described.

586. Rao, K. S. J. Phys. Chem. 45, 531-539, 1941

CEREAL GRAINS: SORPTION HYSTERESIS. Measurements of sorptions and desorptions of water vapour at 30°C on activated rice and dhal grains have revealed a unique colloidal behaviour, i.e. the disappearance of the hysteresis loop originally exhibited. An explanation by cavity concept is offered. On absorption and swelling the grains lose their property of entrapping water. Gum arabic, etc. shew similar behaviour, but with carbon tetra chloride on activated rice, a permanent and reproducible loop was observed.

LIQUID SORBENTS

587. Bichowsky, F. R., Kelly, G. A. Indus. & Eng. Chem. v 27 n 8 Aug. 1935 p. 879-82

CONCENTRATED SOLUTIONS IN AIR-CONDITIONING. Process described employs liquid drying agents; lithium-chloride solutions of high concentrations successfully used; automatic cycle; data on coefficients for transfer of moisture and heat to lithium-chloride solutions in packed tower employing Raschig rings; when dehumidification is employed in connection with cooling, large savings are possible in operating and first costs.

588. Davis et al J. Amer. Chem. Soc. 52 3757-69, 1930 54 2340, 1932

THE ROLE OF LIQUID STATIONARY FILM IN GAS ABSORPTION.

590. Dugger, G. L., O.T.S. U.S.Dept.Comm. P.B.99766.
Thesis.Univ.Florida Sept.1947
LITHIUM BROMIDE - METHYL ALCOHOL. A possible system for Absorption 108 pp. photos, diagrams, graphs, Tables, Micro-film $4.50 Photo. $ 13.75. Data for specific heats, heats of dilution, vapour pressures, densities and viscosities presented graphically for Li.Br. - Me.OH system. Theory is discussed and test apparatus described. Results for various concentrations.

591. Engelbach Food Inds. 20 839 1948
AIR CONDITIONING. GLYCOL SYSTEM CUTS COSTS BY 40%. Triethylene glycol is used and reactivated by exhaust steam. Economical, flexible and allows precision control. Sterilising qualities are a further advantage.

592. Greenewalt Ind.Eng.Chem.18 1291, 1926
Absorbtion and Diffusion into liquids. (H_2SO_4)

593. Hutchinson, Sherwood Ind.Eng.Chem. 29 836 1937
LIQUID FILM IN GAS ABSORPTION.

594. Jordan, C. B., Hatch, V. O. Analytical Chem. 22(1),177-8
Jan.1950
DETERMINATION OF WATER IN GLYCOLS AND GLYCEROL. By Azeotropic distillation with 1.Butanol. The latter breaks the hydrates. Tests from 1 to 95% H_2O gave accurate results.

595. Russell, G. F., Reid, L. S., Trans Amer.Inst.Chem.Engrs.,
Huntington, R. L. 25 June 1945,41,315-325
EXPERIMENTAL DETERMINATIONS OF THE VAPOUR-LIQUID EQUILIBRIA BETWEEN NATURAL GAS AND 95% DIETHYLENE GLYCOL UP TO A PRESSURE OF 200 P.S.I. This experimental study which is related to the dehydration of natural gas by diethylene glycol was undertaken because of the need for equilibria data in the design and operation of high pressure absorption plants. In the laboratory a concurrent vapour-liquid contactor was used for the dynamic mixing of natural gas with a glycol-water solution of known composition. The total water and glycol vapour content of the natural gas was determined by sorption in anhydrous magnesium per-chlorate, while separately the glycol vapour was absorbed in distilled water. The water vapour content was calculated by difference. These equilibria data are presented as a ratio of the mol fraction of the component in the vapour phase to the corresponding mol fraction in the liquid solution. Both water and 95% diethylene glycol equilibrium ratios exhibit minimum values at approximately 1500 p.s.i., passing into the retrograde condensation range above this pressure. A rapid decrease in dehydration efficiency at pressures exceeding 2000 p.s.i. is indicated.

896. Thurston, E. F. J. Soc. Chem. Ind., July 1948, vol. 67, 249-2[illegible]

GAS DRYING BY CALCIUM CHLORIDE SOLUTIONS: MECHANISM OF TRANSFER. experiments have been carried out in a small laboratory packed tower and in a wetted wall column to determine the respective contributions of the gas and liquid films to the transfer of water vapour from moist air into strong solutions of calcium chloride. Comparative tests were also made on the absorption of ammonia from air-ammonia mixtures into dilute sulphuric acid in the wetted wall column. The experimental results have shown that in normal conditions gas drying by calcium chloride solutions may be regarded as a case of predominantly gas film limitation. This information may be used in the design of gas or air drying towers using strong calcium chloride solution as desiccant.

897. Tucker, W. S. Philosophical Trans. 215 A 319-351 1915

HEATS OF DILUTION OF CONC. SOLUTIONS. Methods of Determination Tables. HCl, LiCl., $CaCl_2$, H_2SO_4, Ā, HBr.

898. Tucker, W. H., Sherwood, T. K. Ind. Eng. Chem. 5/1948 40(5), 832-838

VACUUM DEHYDRATION USING LIQUID ABSORBENTS. Lithium salts, zinc bromide, phosphoric acid, glycols, ethylene amine series. Laboratory studies of the physics of the absorption process are studied. The paper relates chiefly to Lithium Bromide solutions.

899. Walker, Lewis, McAdams, Gilliland Princ. of Chem. Eng. p. 38. 1937

The diffusion difficulty prevents the absorption of clouds or vapours in liquids where v.p. of a constituent of the liquid forms a cloud with e.g. HCl, SO_3; For instance 97-98% H_2SO_4 is necessary to absorb SO_3. Above or below this SO_3 vapour or H_2O forms a cloud with the SO_3 to be absorbed and the particles are too large to move through the surface layer. Note the difficulty of absorbing a cloud of NH4Cl in water.

900. Weinelberg, A. Chem. metall. Engng. 1938, 45, 418. Brit. chem. physiol. Abstr. B, 1938, p. 1111

CHEMICAL DEHUMIDIFICATION OF AIR. Methods are reviewed, with special reference to the use of lithium chloride and calcium chloride, and the advantage of using dehumidified air for drying materials is discussed.

SOLID SORBENTS

601. Ahlberg, J. E. Industr.Engng.Chem., 1939, 31, 988

RATES OF WATER VAPOUR ADSORPTION FROM AIR BY SILICA GEL. An experimental study was made of the factors which affect rates of adsorption of a condensable vapour contained in a "non-condensable" gas by a granular adsorbent. Silica gel and air containing different amount of water vapour were used. The effects of temperature of the gas, partial pressure of the adsorbable vapour, rate of gas flow, amount of vapour readily adsorbed, mesh size of the granular adsorbent and thickness of the adsorbent beds were examined. The effect of heat treatment is also considered.

602. Attapulgus Clay Co., Carter, W. S. U.S. 2,467,215 12 April, 1949

DRYING OF FLUIDS. The method of formation and activation of metallic silicates. Absorption of moisture up to 24% from gases or liquids. See Chem. Abstr. 43 13 4907, 10/7/49.

603. Bower, J. H. J.Res.Nat.Bur.Standards, 1944, 33, (3), 199-200; Ceram.Abst. 1945, 24, 19

REVISED RESULTS OBTAINED WITH CERTAIN DEHYDRATING AGENTS USED FOR DRYING GASES. This paper is a revision of a former paper (Bur. Standards Journ. Research, 1934, 12, 241) and as a result of further study, it includes two revised values. New samples of anhydrous magnesium perchlorate or Anhydrone, silica gel, and alumina were obtained and tested for dehydrating efficiency.

604. Brueckner, H. Hirth, L. Angewandte Chemie v 49 n 23 June 6 1936 p 360-2

ALUMINOGEL, ITS MANUFACTURE AND PROPERTIES. Method described of producing amorphous aluminum oxide (aluminogel) from aluminum salt solutions and ammonia; total water absorptivity of completely dehydrated gel is about 40%; regeneration is best effected by heating of gel in air stream to higher temperature (preferably 400 to 4500 C).

605. Cappell, R. G., Hammerschmidt, E. C., Deschner, W. W. Ind.Eng.Chem. 36, 779-784 1944

GASES, DEHYDRATION. Report of a study of silica gel, activated alumina Grade A, fluorite (a natural bauxite, and H1 - fluorite) (fluorite impregnated with 12-14% manganous chloride) for the dehydration of commercial gases. Determinations of absorptive capacities. These decline with continued use and reactivation. Oil vapours, etc., also cause deterioration. Temperature, pressure, specific heat and molecular weight affect the dehydration of gases. The effects are discussed. Pressure drops and reactivation heat requirements are studied. Heat balances shew that the heat required approximates to the latent heat of vaporisation.

The dehydrogenation effect on paraffin hydrocarbons (with monomolecular water layers) and the inhibition of this effect are discussed. Heat requirements for reactivation: R.B. Derr. Ind.Eng.Chem. 30 384-8, 1938 J.M. Lednum, Am. Gas. Assoc. Proc. 1934, 664-80 26 other references.

606. Carter, J. W. — Chem.Tr.Jnl. 2 Feb.1951, 128, (3322), 275-6. Paper to Inst. of Fuel, 30 Jan.1951

DRYING AIR AND GASES BY ADSORPTION METHODS. After a brief reference to other methods, the use of solid adsorbents is described. The properties of alumina and of silica gel and features of plant design are discussed. Particular reference is made to the heat of absorption and its disposal and to the precautions necessary to avoid the presence of water on the dry side of the bed. Two types of plant are described (a) for high efficiency (b) for air-conditioning including a completely continuous plant. Regeneration is discussed.

607. Cook, S. V., Waring, C. E., Gen. Motors Corp. — U.S.P.2,388,390, 6/11/45 B.I.400 May, 1949

DESICCATING AGENT. Anhydrous calcium sulphate is coated with cellulose acetate (15% acetone solution) to give a moldable water-permeable product, suitable for use as a dust free drying agent.

608. Davison Chemical Corporation — Bulletins and Descriptive pamphlets

The pamphlets deal with the various aspects of use and properties of silica gel, and with details of equipment construction.

609. Dehler, F. C. — Chem. & Met.Engr.May,1940, 307-310

SILICA GEL ABSORPTION. Moisture relations presented graphically.

610. Derr, R. B., Al. Co. Res. Lab. — Ind.Eng.Chem. 30,(4),384-388, Apr.1938

DRYING AIR AND COMMERCIAL GASES WITH ACTIVATED ALUMINA. The temperatures developed may be above 100°C and removal of this heat increases capacity for absorption. Graphic representation of absorption rates, humidity and gas quantities are given. Complete and partial drying are discussed. Illustrations of plant.

611. Druce, J. G. F. — Soc.Chem.Industry — J (Chem. & Industry) v 54 n 3 Jan.18 1935 p.54-5

MAGNESIUM PERCHLORATE ("ANHYDRONE") AS DRYING AGENT. Dehydrating properties of magnesium perchlorate briefly discussed.

612. Elkin, P. B., Shull, C. G., Roess, L. C. Industr. Engng. Chem. Industr. Ed. 1945, 37, 327-331

SILICA-ALUMINA GELS. SPECIFIC SURFACE AND PARTICLE SIZE DISTRIBUTION. Three series of silica-alumina gels of various concentrations, made by (A) precipitation in sequence, (B) mixing wet gels, and (C) impregnation of partially dried silica gel, were examined by nitrogen adsorption, small angle x-ray scattering, and x-ray diffraction. Specific surfaces were smaller for A and larger for B than those expected for mixtures of the dried silica and alumina gels. Maxima in curves for specific surface vs. alumina content for B and C at about 5% by weight correlated with minima in average particle size. No alumina was detected by x-ray diffraction for gels containing as much as 26% by weight alumina.

613. Frary, F. C. Ind. Eng. Chem. 38, 129, 1946

ADVENTURES WITH ALUMINA. Electron micrographs of alumina and X-Ray Diffraction Patterns are given. A general description of aluminum compounds.

614. Hammerschmidt, E. G. Gas. Jan. 1945, 21, 32-3

GAS DEHYDRATION. A description of a gas dehydration plant erected by Texoma Natural Gas Co. in 1940, and information as to its performance are given. Activated alumina was used but its efficiency in absorbing water rapidly declined during operation. Several commercial absorbents were studied and Florite, an activated bauxite ore containing iron was chosen. Details as to its performance are given. From experiments it is concluded that such solid absorbents are adversely affected by the regenerative cycle and that the decline in capacity is due to the combined effect of heat and moisture on the absorbent.

615. Hartley, A. W. Manufng. Chem., 1946, 17, 144-6; Brit. Abstr. B. I., 1946, 253

DRYING OF AIR AND GASES. The properties and efficiency of Al_2O_3, SiO_2 gel, and $CaCl_2$ as drying agents in industrial processes are discussed.

616. Harwood, J. H. Industr. Chem., 1946, 22, 651-5, 721-5

ACTIVATED ALUMINA: APPLICATIONS. A review of recent developments in the application of activated alumina to the drying of gases and liquids, the absorption of organic vapours and the reclamation of transformer oils. Data are provided on the thermal conductivity, rate and efficiency of moisture sorption at various temperatures and relative humidities, and the sorption of several common organic solvent vapours. Attention is paid to the use of alumina as a desiccant in packaging.

617. Heinemann, Heinz, Wert, R. W., McCarter, W. S. W. — Ind. Eng. Chem. 41, 12, 2929, Dec. 1949

ORGANIC DEHYDRATION REACTIONS USING ACTIVATED BAUXITE. Dehydration of Alcohol, and temperature of activation of the bauxite. The remainder of the paper deals with catalytic molecular dehydration by bauxite of alcohols, Ketones, etc.

618. Kimberlin Jr., C. N., Pierce, J. A., Standard Devt. Co. — U. S. 2,503,913, 11/4/1950

DRYING INORGANIC HYDROGEL PARTICLES. The use of butyl alcohol or other partially water mescible solvent, containing about 0.5% of a surface active agent such as lecithin, organic sulphate or sulphonate or other wetting agent. The granules resulting have low apparent density, as required for catalysis.

619. La Lande Jr., W. A., McCarter, W. S. W., Sanborn, J. B. — Ind. Eng. Chem. 1944 36, 99-109

BAUXITE. USE AS A DRYING ADSORBENT. The activation of tri-hydrated Bauxites at temperatures up to 1600°F has been studied, for production of an efficient drying absorbent. Data on moisture relations under various conditions are presented. The mechanism of thermal decomposition is discussed and X-Ray diffraction analysis. Maximum capacity is obtained by activating at 700-750°F where moisture is reduced to 6-8%. Bauxite after activation will absorb 11-16% of water, and regenerates repeatedly at 300- 350°F. Physical factors for drying are discussed and results on drying gases and liquids are given.

620. La Lande, W. A., Attapulgas Clay Co. — U.S.P. 2,388,616, 6.11.45 B.I.400 May, 1949

DEHUMIDIFYING AGENTS. Bentonite, acid activated bentonite, and fullers earth are heated at 120 to 260°C for several hours to remove free H_2O and 18-70% of combined H_2O and give products suitable for drying agents.

621. Milligan, W. O., Rachford, Jr., H. H. — J. Phys. Colloid Chem., 1947, 51, 333-359

SILICA GEL: SORPTION-DESORPTION HYSTERESIS: EFFECT OF HEAT TREATMENT. Sorption-desorption isotherms have been obtained for a series of silica gels that had been subjected to systematic heat-treatments from room temperature to about 1,000°C. Twelve complete isotherms are represented which show that the characteristic hysteresis loop is not destroyed by moderate or even excessive heat-treatment. Pore distribution curves are also given, and it is seen that heat-treatment of the original gel does not appreciably modify the distribution or the size of the pores, but does appear to diminish their number. The surface area of the various samples is shown as a function of temperature of heat-treatment, and it is apparent that heat-treatment at temperatures about 200°C. increases the available surface slightly, and that additional heat-treatment at higher temperatures decreases the available surface in a regular manner.

622. Milligan, W. O. J.Amer.Chem.Soc.,70,2922,1948
Rachford, H. H.
THE SORPTION-DESORPTION HYSTERESIS CHARACTERISTICS OF THE SYSTEM SiO_2-H_2O GEL AT THE BULK FREEZING POINT OF WATER. Experimental work reported in the literature has shown that substances in the sorbed condition held by so-called capillary condensation forces may not exhibit anomalous behaviour as the temperature is allowed to vary through values at which phase transitions in the bulk condition normally occur. To study further this behaviour, a set of sorption-desorption isotherms for water vapour on several silica gels was measured at -5°C. The sorption characteristics of the same samples had previously been determined at 12°C so that a comparison showing the effect of sub-freezing temperatures on the isotherm could be made. It was found that when the sorption was plotted against the relative saturation, the isotherms at the two temperatures coincided only if the saturation pressure was taken to be the experimentally determined value for supercooled water at that temperature. On this basis there is suggested a procedure for the estimation of the minimum possible "freezing" and "melting" points, which would yield an explanation of observed freezing-melting hysteresis phenomena consistent with the hysteresis observed in the sorption-desorption isotherms. (5 figs.).

623. Moles, E., Roquero, C. Anales soc.espan.fis.quim.31,11-25(1933)
COMPARATIVE STUDY OF SOME DEHYDRATING AGENTS. The literature on the effectiveness of the usual gas-drying agents is reviewed, and preliminary results are given for SiO_2 gel, anhyd. $Mg(ClO_4)_2$, BaO and B_2O_3. The method involved passing a current of air at constant temperature saturated with H_2O vapor at room temperature, at known velocity over a known quantity of dehydrating agent. The gas was then passed over a weighed P_2O_5 tube to collect the H_2O not retained by the material under test. The effectiveness is expressed in %. As stated in the literature, SiO_2 gel is as effective as P_2O_5 up to the point where $2\ SiO_2.H_2O$ forms. Anhyd. $Mg(ClO_4)_2$ absorbs H_2O completely up to the point where $Mg(ClO_4)_2 . 4 . 5H_2O$ forms. Freshly calcined BaO compares well with P_2O_5 up to the point of formation $BaO.H_2O$. B_2O_3 is the least effective, and its preparation and handling are very difficult.

624. Othmer, D. F., Sawyer, F. G. Ind.Eng.Chem.35,1271,1943
CORRELATING ADSORPTION DATA. Data on sorption of various gases on charcoal.

625. Allen, Patrick J.Phys.Chem.38,771,1934
THE DIFFUSION OF ELECTROLYTES IN SILICA GEL.

626. Peck, W. C. Chemical Products, May,1939
ACTIVATED ALUMINA. A description of industrial applications.
5 pages.

627. Plank, C. L., Socony Voc. Oil Co. U.S. 2,499,680 7/3/50
SPHEROIDAL DESICCANT. Method of producing spheroidal silica gel of p.H. 5-10, by injecting into gas oil, with chemical treatment of the gel before and after injection.

628. Rao, K. S. J.Phys.Chem. 45,500-512,1941
TITANIA GEL-WATER SYSTEM: SORPTION HYSTERESIS. Study by use of a McBain-Baker quartz fibre spring balance. Sorption of water at 30°C titania gel had a remarkably permanent hysteresis loop after 32 cycles. Explained by cavities with constricted ends. After some months there is a drift, indicating a change in the gel and size of capillaries.

Application of the Langmuir and the William-Henry equations for monomolecular adsorption shew a clear transition from monomolecular to capillary condensation. Analysis of the loops indicate that the vapour of the water at the necks of the capillaries is the controlling factor for evaporation and emptying.

The true equilibrium curve is the sorption curve, because at desorption the cavities retain the liquid in a metastable condition.

629. Rao, K. S. J.Phys.Chem. 45,513-517,1941
SILICA GEL-WATER SYSTEM. SORPTION HYSTERESIS. The loop was permanent to 19 cycles. Scanning gave convincing proof of the concept of cavities with constricted ends as a general cause of hysteresis. Comparisons with titania gel-water system.

630. Reid, L. S., Ku, C. C. Okla.Agr. & Mech. Coll.Pamphlet Jan.1943
DEHYDRATION OF NATURAL GAS BY MEANS OF SOLID ADSORBENTS. Determination of the equilibrium adsorption, characteristics of three solid adsorbents, predominantly hydrous aluminium oxide, when contacted by gas saturated with water vapor and small percentages of heavier hydrocarbons; effect of the presence of hydro-carbons on adsorption of water has been determined; also effect of presence of water on adsorption of hydro-carbons.

631. Schulze, W. A., Phillips Petr.Co.Amer. U.S.P. 2,356,590,
29.8.1944
Non aqueous fluids dried by contact with Bauxite, impregnated with 3-13% of hygroscopic salt, e.g. LiCl, so that the concentration of salt increases in concentration on the bauxite in the direction of flow.

632. Sersale, R. La Ricerca Scientifica 20,(11),
pp.1685-1698 Chem.Age. 64,(1646),
27 Jan.1951
THE THERMAL ACTIVATION OF BAUXITE. Discusses the changes effected by thermal treatment on Italian Bauxites.

633. Peter Spence & Sons Ltd., Manchester Brochure 33 pp. 1949
ACTIVATED ALUMINA. Physical Characteristics, Data, Uses, Analysis.

634. Taylor, R. J. J.S.C.I. 68, (1), Jan. 1949, pp. 23-26
THE ACTIVATION OF ALUMINA. An investigation of the physical transformations of y. Aluminium Trihytrate when dehydrated by heat, and the effect on adsorptivity and porosity. Tables, curves, Review of literature. 16 References.

635. Taylor, R. K. Ind. Eng. Chem. 37, 649-652, 1945
SILICA GEL. ADSORPTION OF WATER VAPOUR. Data for adsorption over the range 25°-250°C were obtained by the static method in absence of air. The relation, R.H./Temperature, appears to be linear over the range of measurements. The pressure-temperature points lie on converging straight lines.

636. Wiig, E. O., Juhola, A. J. J. Amer. Chem. Soc. 71, 561-568, Feb. 1949
ABSORPTION OF WATER VAPOUR ON ACTIVATED CHARCOAL. Charcoal granules exposed to water vapour undergo an initial contraction, followed by expansion as the water vapour pressure is increased. A semi empirical relation based on theories of capillary condensation is proposed. The density of the adsorbed water was slightly less than unity.

637. Wilkinson, E. R., Stern, B. J. Petroleum Engineer, 22, (7), D30-35
Reference Annual 1950
USE OF SOLID ADSORBENTS IN NATURAL GAS DRYING. Describes an adsorbent designated S/V Sovabead, and compares it with Activ. Alumina. Curves shew its capacity to be about twice that of Alumina, but only half that of silica gel. Has good strength, Its composition is not given. Bibliography.

638. Williams, E. C. Chem. Eng. Group J. Soc. Chem. Ind. 5 & CA, [illegible] (1923-24)
SILICA GEL AS AN INDUSTRIAL ADSORBENT. Excellent discussion with data on benzol and water vapor. Description of industrial applications.

AIR CONDITIONING AND GAS DRYING

639. ——— Gas World 87, 28, 1927
DRYING TOWN GAS BY CALCIUM CHLORIDE SOLUTION.

640. Anon Am. Gas. Assn. - Convention Paper, 1930,
26 pp., 14 figs.
GAS DRYING. REPORT OF COMMITTEE ON DEHYDRATION. Experience at Grand Rapids during period of operation of plant; several curves have been prepared which show exact conditions as encountered; Reports of Subcommittees on Ground Temperature Determination, Operation, and on Oil Fog Lubrication and Rehydration.

641. —— Illinois Univ. Eng. Exp. Stn. Circular No. 37
March, 1939
2nd CONFERENCE ON AIR CONDITIONING, 152 pp. The first conference in 1936 was reported in circular No. 26.

642. Anon. Refrig. Engng. 42, (1), 296, July, 1941
A SURVEY OF THE USES OF AIR CONDITIONING.

643. Anon. Engineering 29 June, 1945, 159, 517-8
AIR DRYING BY ACTIVATED ALUMINA. The article describes the series of "Lectrodryers" for the drying of gases, in which beds of activated alumina are used. Gas flows of 100-360,000 cub. ft./hr. can be handled by various sizes of equipment. Reactivation is by heating, in the smaller sizes by electricity, in the larger by electricity, gas or steam.

644. Anon. Nat. Petrol. News, 5 June 1946, 38, R-421-439
NEW GLYCOL DEHYDRATION PLANT REDUCES GAS DEW POINT [illegible]. The Agua Dulce Dehydration Plant of the Tennessee Gas and Transmission Co. has installed three contractors which can handle 300 mmcf/day of gas at 840 psig and reduce the dew point from about 80°F. The units are in parallel and use diethylene glycol as the dehydrating agent. Details of construction and operation are presented.

645. Anon. Petrol. Refin., Feb. 1946, 25, 67-8
DIETHYLENE GLYCOL PLANT DEHYDRATES GAS TO EXACT SPECIFICATION. An Automatically-controlled diethylene glycol plant for moisture control of residue gas from gasoline plant operations is described.

646. ——. Ind. Chemist. 40, (10), 657, Oct. 1948
DRYING GAS FROM PYRITES BURNERS BEFORE CONVERSION OF SO_2 to SO_3. Absorption in 90-95% sulphuric acid.

647. —— Gauthier-Villars, Paris, 255 pp. 1948
VENTILATION INDUSTRIELLE ET MINIÈRE. Covers heating, air conditioning, dust removal and drying.

648. Advt. Chem. Eng. News 28, 7, 469, 13 Feb, 1950
NEW METHOD GIVES PRECISE CONTROL IN AIR CONDITIONING. "Niagara" controlled humidity method uses Hygrol, a hygienic, liquid absorbent. (Probably glycol for it is a liquid spray, with cooling, passing out to a concentrator and back to the spray). 1,000 to 20,000 CFM. Generally for temperatures 35°F and upwards. Below Fr. Pt. the Niagara "no frost" is applicable.

Niagara Blower Co.,
Dept. C.E. 405, Lexington Avenue,
New York, 17.

649. ----
AIR CONDITIONING. See also under "Textiles".

650. ---- F.I.A.T. Report No. 500
F.I.A.T. Report No. 969
1. Drying and Purification of Acetylene.
2. Drying of Acetylene.

651. Akilov, B. P. Promyshlennaya Energextika No.7, P. 11, July, 1949
METHODS OF DRYING COMPRESSED AIR.

652. Allen, J.R., Walker, J.H., James, J.W. McGraw Hill Book Co., New York, 1946, 676, pp.
HEATING AND AIR CONDITIONING. A textbook.

653. Alt, H.L. Domestic Eng. Co. Chicago, 1936, 260pp.
PRACTICAL AIR CONDITIONING. For designer etc. Chapter on automatic controls.

654. Amero, R.C., Moore, J.W., Capell, R.G. Chem. Eng. Progr. 43, (7), 349-370, 1947
DESIGN AND USE OF ADSORPTIVE DRYING UNITS. A general and thorough review of adsorption processes with particular reference to natural gas etc. Considerable fundamental data is given. Effects of impurities on sorbent. A tabular comparison of the properties of over 20 drying agents, solid and liquid is given, and a table of performance characteristics with gases and organic liquids when using "florite", a porous, non-corrosive bauxite prepared by the Floridin Co., Adsortion curves etc. are given for this material. 126 references. Discussion and curves for viscosity of paraffinic hydrocarbons with molecular weights and pressure. Illustrations of dew point testers.

655. Anders Co., Chem. Eng. 56, (3), 156, March, 1949
420, Lexington Avenue, N.Y. 17.
AIR DRYER. Capacity 15-750 c.f.m. at pressures 30 to 150 p.s.i. and inlet temperatures from 40-120°F. Steam or electric, convertible, automatic.

656. Baldry, E. W. J. Text Inst. June, 1950 41, (6), 288-298
AIR CONDITIONING. Reasons for air conditioning are given, particularly with reference to textile mills. The principles underlying the various requirements and of the conditioning process are given and flow diagrams and curves for the three main sets of conditions are included. The advantages and necessity of air filtration are illustrated.

657. Barr, W. T. Cotton (U.S.), 1946, 110, No.9, 75
PSYCHROMETRIC CHARTS: APPLICATION. The use of psychrometric charts in considering proposals for air conditioning systems is explained and the General Electric Co.'s chart is reproduced in a convenient size (11 x 6 ins.).

658. Bateman, P. J. R.A.E. Farnborough Tech.Note Aero. 1972, S.D.83, Aug, 1948, D.S.I.R. Records
TESTS WITH AN AIR TURBINE AND HEAT EXCHANGER CONSIDERED AS AN AIR DRYING PLANT. It is intended that with a heat exchanger between the inlet and exhaust systems of a turbine, the low temperatures due to expansion of the air in the turbine will precipitate water or ice from the air stream in the heat exchanger.

659. Behringer Z. Ver. Deut. Ing. Beiheft Folge. 5, 190-3 1937
MODERN METHODS OF AIR DRYING. (Transl.).

660. Bercumshew J. Chem. Soc. 2213, 5. 1930
THE DRYING OF GAS STREAMS.

661. Bichowsky, Kelly
AIR CONDITIONING. See under "Sorption".

662. Blohm, C. L., et al World Oil 130, (7), 1950
PURIFICATION AND DEHYDRATION OF GASES. Removal of H_2S and water by glycolamine solutions.

663. Bower, J. H. U.S. Dept. Commerce Nat. Bureau Stds. Res. Paper 1603
REVISED RESULTS OBTAINED WITH CERTAIN DEHYDRATING AGENTS USED FOR GASES.

664. Brueckner, H., Ludewig, W. Gas - u Wasserfach v 77 n 9 Mar. 3 1934 p 132-7
GAS DRYING. (GASTROCKNUNG.) Review of process, advantages and disadvantages of drying of gas by silica gel absorption and other methods

665. Brueckner, H., Ludewig, W. Gas - u Wasserfach v 78 n 24 June 15 1935 p 459-62
GAS PURIFICATION. (TROCKNUNG UND REINIGUNG VON STADTGAS MIT KIESELGEL.) Drying and removal of residual impurities of town gas with silica gel; advantages of silica-gel drying are simple apparatus, small heat consumption during regeneration, accompanying gas purification; disadvantages are high initial cost of gel, and necessity for cooling gel during absorption.

666. Bryant, E.S., Wickstrom H.W. Gas, May 1946, 22, No.5, 80, 82
DIETHYLENE GLYCOL DEHYDRATION PLANT. The major part of the gas supply for the City of Long Beach (Calif.) is treated at the plant of the Wilmington Gasolene Co. at Terminal Island for removal of water. This plant which was completed in October, 1945, operates at relatively low pressure and the saturated gas has a high specific water content. A study was made of the average and peak loads and a plant designed that would remove sufficient water from the gas to prevent condensation in the distribution system when operating at winter rates and allowing sufficient humidity during the lighter loads to prevent dust formation in the distribution system and the drying up of meter diaphragms. The plant is capable of reducing the dew point of 15 MMcf of gas a day more than 30°. This results in the removal of approximately 5250 lb. of water per day when the entering gas temperature is 80°F. and the pressure 35 psi. Diethylene glycol is used as the dehydrating medium. A flow diagram of the plant is included.

667. Buchan, R. C., et al World Oil 130, (6) 1950
DEHYDRATION OF NATURAL GAS. Wet type dehydraters (liquid absorbents) are usually cheaper to install. Dry type absorbers give lowest water content.

668. Carlson, H. C. Industr. Engng. Chem., Jan. 1946, 38, 14-15
ABSORPTION AND HUMIDIFICATION. Articles appearing in this field from October 1944 to November 1945 are briefly reviewed. Work of particular interest to the gas industry is as follows: (1) Goff and Gratch-Heating, Piping and Air Conditioning 17, 334, (1945). The thermodynamic properties of air, water and their mixtures are treated. (2) Walthall, Miller and Striplin - Trans. Amer. Inst. Chem. Engrs. 41, 53, 1945 relate studies on the absorption of SO_2 and O_2 in water containing additional agents to form H_2SO_4. (3) Articles on drying natural gas by diethylene glycol by Hull and by Russell. (4) Articles on absorption of CO_2 are listed.

669. Carrier, W. H., Busey, F. L. Trans. Amer. Soc. Mech. Engrs. 33, 1055-1129, 1911
AIR CONDITIONING APPARATUS. Principles governing its application and operation. Diagrams of humidity control instruments. Tables. curves, illustrations.

670. Carrier, W.H., Cherne, R.E., Grant, W.A. Pitman Publ. Corp. New York, 1950, 560, pp.
MODERN AIR CONDITIONING, HEATING AND VENTILATION. Includes a new treatment of automatic control.

671. Carter, J. W. Inst. of Fuel "Drying Study", Jan. [illegible]
DRYING AIR AND OTHER GASES BY ADSORPTION METHODS. The properties, uses and methods of employment of alumina and silica gel desiccants. Adsorption curves and illustrations of equipment are shown.

672. Chester, T. Belfast Assn. Engrs. Paper No. 102, 1937
24 pp.
AIR CONDITIONING APPLIANCES.

673. Chapin, W. F., Flora, C. L. Calif. Oil Wld, June 1948, vol. 41, 3,
5-7, 9-10, 12-13, 15, 17
PURIFICATION AND DEHYDRATION OF GASES. The subject of removal of H_2S, CO_2 and water vapour from gas is treated particularly with respect to usage of aqueous monoethanolamine and aqueous glycol-amine solutions. Flow sheets, some engineering data and limited cost data are given. It is stated that a plant treating [illegible] /day of sour gas containing [illegible] acidic material costs $300,000.

674. Claude, G. Comptes Rend. 157, 466, (1913)
DRYING OF AIR TO BE LIQUIFIED. Suggests using one at a time of two sets of heat interchangers - the returning gas passing back through one to clean the ice out.

675. Coey, S. C. Refrig. Air-Condit. (Canada), 1939, 5
(No. 2), 15
CHEMICAL DEHUMIDIFICATION. Discusses the use of chemical dehumidification for controlling relative humidity. The 3 different classes of dehumidifier, (1) adiabatic, (2) isothermal and (3) calorider (boiling and air evaporating method), are described in detail.

676. Cowen, W., Storrow, J. A. J. Soc. Chem. Ind. 64, (12), 334-5,
Dec. 1945
SULPHURIC ACID AIR LIFT USED AS AN AIR DRIER.

677. Davison Chem. Corp. Balt. 3. U.S. Process Bulletin No. 301
INERT GAS FOR BLANKETING AND PROCESS. Generation, application, diagrams.

678. Dawe, H. F., Wade, H. N. Petrol. Refiner, 23, 430-2, 11/1944
HIGH PRESSURE DEHYDRATION UNIT (FOR NATURAL GAS). Conforms to Refinery Piping Code.

679. Dawe, H. F. Petrol. Engr, 1946, 17, No. 6, 119-22
PACKAGED TYPE DEHYDRATION PLANTS. Water is removed from natural gas by passing the gas through a granular absorbent. Compact, easily assembled equipment for this type of operation is described, and flow diagrams are given.

[illegible]. Dole, W. S. Gas World (Lond.), vol.93, No.2404, Aug.30, 1930, pp. 181-182
DESATURATION OF GAS - EXPERIENCE WITH COMPRESSION METHODS IN SMALL PLANTS. Abstract of paper read before Can. Gas Assn., previously indexed from Gas Jl., July 30, 1930.

81. Fischer, K. Chemiker-Ztg v 59 n 51 June 26 1935 p 516-7
EIN NEUER WEG DER GASTROCKNUNG. Gas drying with glycerin; results of drying town gas by this process which has not yet been adopted in any German works.

[illegible]. Fowler, J., Diggle, H. and Metropolitan-Vickers Electrical Co., Ltd. B.P. 619,993, 14.11.46
DEVICE FOR DRYING AIR (BREATHERS). A transparent cup-shaped vessel (V) containing a drying agent is mounted under a cover plate. The bottom of V has several air-inlet apertures, and two concentric flanges extending downwards. These flanges dip into an oil-seal cup which screws on to V. rendering the apparatus air-tight when not in use.

83. Francois, A. J. Fr.P. 892,439/1944, Chim. et Ind. 53, 327 5/1945
DRYING AND DEHYDRATION OF GAS FROM PRODUCERS OR OTHER SOURCES. The gas is passed directly or indirectly in contact with calcium carbide.

84. Frigidaire Ltd., and Murdoch B.P. 575,593/1946
GAS DRYING APPARATUS.

[illegible]. Gilliland, E. R.
FUNDAMENTALS OF DRYING AND AIR CONDITIONING. See under Principles, general.

86. Goodman, W. La Crosse, Wisconsin, 1938, 354 pp.
TRANE CO. AIR CONDITIONING MANUAL.

87. Granville, B. U. SP. 2,409,624, 1946
APPARATUS FOR EXTRACTING MOISTURE FROM ATMOSPHERIC AIR.

[illegible]. Greaves, R. L. Gas Jl., vol. 193, No. 3540, Mar. 25, 1931, pp. 797-799 and (discussion) 799, 1 fig.
PARTIAL DEHYDRATION OF TOWN GAS. Advantages of partial dehydration; possible disadvantages of gas drying; choice of method; choice of best position to install dry gas plant lies between inlet side and outlet side of gasholders; Holmes dri-gas process at Shrewsbury; supervision. Before Midland Junior Gas Assn.

689. Matthew Hall & Co. Library Catalogue recd. Aug. 1949
Technical Books, Periodicals on Air Conditioning, Heating, Ventilation, Plumbing, Lead, Electricity, Refrigeration, Fire, Miscellaneous Engineering. 19 Books on Air Conditioning. 36 American Publications on Air Conditioning.

690. Herkimer, H., Herkimer, H. Chem. Publ. Co., New York, 1947, 702pp.
AIR CONDITIONING. Glossary pp. 602 to 653. Illustrations.

691. Hirsch, M. Industrial Chemist, 1941, 17, 291-293
(G)-HEATING, VENTILATION AND HUMIDIFICATION. WATER VAPOUR CONDENSATION FROM AIR. The condensation of water vapour on a cooling surface of air at one temperature with a stream of air at a higher temperature and with a higher moisture content are studied, and the influence of the presence of nuclei and the effects of turbulent air flow are explained. Supersaturation of air is discussed in relation to refrigeration and air conditioning. Methods of preventing supersaturation are outlined.

692. Hock, H. Glueckauf v 68 n 1 Jan. 2, 1932, p. 18-19
DIE TROCKNUNGSVERFAHREN FUER KOHLENGAS. Advantages and technical difficulties of drying gas; four drying systems are discussed: us of salt solutions or liquids which absorb moisture; cooling to low temperature; simultaneous compression and cooling, and adsorption of moisture by materials with coarse surfaces (silica gel).

693. Holden, E. C. Chem. & Met. Eng. 28, 801-4, 1923
METHODS OF AIR DRYING. Comparison of and data on various methods, including use of solid adsorbents e.g. fullers earth, silica gel.

694. Hougen, O.A., Dodge, F.W. Ann. Arbor: Edwards Bros. Inc. 199pp., 1947
THE DRYING OF GASES. A general account of the drying of gases. Bibliography. See Chem. Eng. News 26 1726 7 June, 1948.

695. Howlett, E. Textile Manufacturer, 1948, 74, 479-483
STURTEVANT AIR CONDITIONING SYSTEM. Modern air conditioning technique is discussed, and an account is given of the main feature of the latest Sturtevant equipment, designed for ventilation, fog elimination, heating, cooling and dust extraction.

696. Hull, R. H. Gas., 1945, 21, No. 5, 23-4, 26-7; Gas Age 17 May, 1945, 95, No. 10, 26-9; Chem. Abstr. 1945, 39, 2859
DESIGN OF THE GOLETA DEHYDRATION PLANT. Natural gas withdrawn fro storage in the Goleta field is dehydrated by means of diethylene glycol at a pressure of about 1,050 lb./sq. in.; this depresses the dew point approximately 40°F. below the incoming temperature of 70-78°F. The plant is designed to treat 150,000,000 cu. ft. of gas per 24 hrs. and is designed for 20% overload. The resultant

dew point is safely below the ground temperature. The diethylene glycol is reconcd. in a rectifier provided with a reheater. All controls, automatic devices, etc., are either pressure-or temperature-operated, so the electricity is required only for lighting.

697. Ingels, M., Carrier Corp. Ind.Eng.Chem.,30(9),990-3,Sept.1938
AIR CONDITIONING EQUIPMENT. Design, Selection and Efficiency. An outline of the functions and the essential features of an all year round air conditioning equipment. 1. Temperature. 2. Moisture control and methods of humidifying. 3. Motion of air. 4. Cleanliness. 5. Cost. Excellent diagrams and illustrations are included.

698. Jennings, B.H., Lewis, S.R. Scranton: Internat.Textbook Co., 1944,507pp.,27/-; Instn.Mech.Engrs. J.,Dec.1945,151
AIR CONDITIONING AND REFRIGERATION. On underlying principles with numerous examples and solutions, and many tables. There are chapters on humidity calculations; heat transfer coefficients; steam, hot-water, and warm-air heating; boilers; and refrigeration theory and apparatus.

699. Jones, B.M., Hunt, R., M/c. Co. U.S.P.,2,373,896.,17.4.45, B.I.118,Feb.1949
CENTRIFUGAL AIR DRYER.

700. Joselin, E. L. Ed.,Arnold & Co.,London,2nd.Ed.1947, 328pp.
VENTILATION AND AIR CONDITIONING. See also Brit. Science News 1 9, 1948.

701. Klemstedt, H. Brennstoff-Chemie v 18 n 2 Jan.15,1937 p.23-4
EIN NEUES VERFAHREN ZUR BEHANDLUNG VON TECHNISCHEN KOHLENWASSERSTOFFEN, ETC., New patented method for treatment of hydrocarbons, with special reference to complete drying by means of solid and dissolved caustic soda; about 0.36 lb. of caustic soda is required per ton of benzol dried and cost of treatment is much less than when using calcium chloride and silica gel process.

702. Knowles, A. F. H. Gas J.194,347-9,(1931),May 6
THE "GLYCERIN" GAS DRYING PROCESS. Installation of gas drying plant at Colwyn Bay Gas Works, in operation 2½ years; result of test, to illustrate conditions of winter and summer working; data on plant at Ilkeston Gas Works.

703. Krull, F. R. Z. kompr. flussige Gase 30, 1-3 (1933)
INTENSIVE DRYING OF CYLINDER OXYGEN WITH SILICA GEL. Two high-pressure absorbers are connected in parallel so that one can be regenerated by N_2 and electrical heating while other is in operation. Each absorber dries 15,000 cu. m. O_2 to moisture content of 10 mg./cu.m. and will over most of this range dry to 2-3 mg.

704. Kut, D. Ind. Heating Engr. 13, Nos. 64-5-6-7, 1951
THE FUNDAMENTALS OF AIR CONDITIONING. A series of papers dealing with the fundamental and practical aspects of air conditioning. Examples, illustrations, charts.

705. Ledoux, E. Electricite v 21 n 30 Mar. 1937 p. 129-31
L'AIR SEC DANS LE DOMAINE DE L'ELECTRICITE. Notes on usefulness and application of dry air in electric industry in manufacture of cables, condensers, dehumidification of stockrooms, paint drying, etc.

706. Lees, S. Engineering 134, 458-60 (1932)
PRODUCTION OF DRY AIR, WITH PARTICULAR REFERENCE TO THE SILICA GEL METHOD. The theoretical work required to remove isothermally water vapor to change a definite quantity of air from an initial to lower humidity is: $W = RT_0 [M_1 \log (p'1/p1) + M_2 \log (ps/p2) - M'_2 \log (ps/p'2)]$, where W is the work required at temperature T_0 abs. to change the water vapor content from M_2 to M'_2 g. mols; M_1 is g. mols (dry) air; R is the gas const.; ps is satn. vapor pressure of water at temperature T_0; p1 and p2 are initial partial pressures of the air and water vapor, respectively, while p'1 and p'2 are the corresponding final partial pressures. The operating advantages of silica-gel dehydration plants are reviewed.

707. Lewis, E. H. J. Iron and Steel Inst. 9/1927. Engineering p. 853 30 Dec., 1927. J. Soc. Chem. Ind. 46, 902, 1927
DRYING AIR BLAST BY SILICA GEL. Large air drying plant in Scotland, drying 35,000 c. ft. min, using Silica gel. See Indust. Chemist 3 441 1927 for complete description of plant.

708. van Liempt, J. A. M. Rec. Trav. Chim., 1942, 61, 341-347
GASES: DRYING. An approximate equation is derived which gives the water vapour content of gases after having passed through a drying plant as a function of the length of the pipe, the velocity of the gas, the pressure, and the temperature. The formula shows satisfactory agreement with experimental data. Practical hints for technical calculations are given.

709. Lumb, C. F. B.P.571,515/1945
APPARATUS FOR DRYING AIR AND GASES. This invention relates to apparatus for drying, or reducing the moisture content of air or gases and is concerned with the provision of apparatus, which is capable of being included in a compressed air or gas supply line to remove oil, grease or moisture from the air or gas prior to its delivery for use, as in a spraying apparatus or pistol, pneumatic tools, hammers etc.

710. Maille, J., Roth, J. B.P. 527,401.1939
AIR CONDITIONING APPARATUS. The principle of a spray, suitably applied and controlled to a current of air.

711. Marlow, T. G. Crosby Lockwood & Son, London, 1910, 326pp.
DRYING MACHINERY OF PRACTICE.

712. Mickley, H. S., (M.I.T.) Chem.Eng.Progr.45, 12, 739-748, Dec.1949
DESIGN OF FORCED DRAFT AIR CONDITIONING EQUIPMENT. The enthalpy potential method. A simple improved method for the design of forced draft equipment.

713. Miller, E. B. Chem.Met.Eng.23, 1155-1219-1251, 1918
DRYING AIR BY SILICA GEL.

714. Morley, R. J. B.I.O.S. Report No. 1142
WINTERSHALL SCHMALFELD PROCESS. The drier is a chimney up which the moist synthesis gas passes and meets pulverised coal coming down the shaft. Gas at 1,000°C explodes each particle of coal, with presumably decomposition of the H_2O vapour.

715. Morris, A. Gas Jl., 192, No. 3528, Dec. 31, 1930, p. 971
THE "DRI-GAS" PLANT AT ST. ANDREWS. Advantages of dehydration of gas; plant described consists of brush washer with two units, each of six washing chambers driven by steam engine situated between them; gas is dried in first unit of washer, through which it passes, and naphthalene is extracted from it in second. Paper read before Scottish Junior Gas Assn.

716. Palmatier, E. P. Heat.Vent., July 1946, 43, 66-72
"THERMODYNAMICS" FOR AIR CONDITIONING ENGINEER. The subject of thermodynamics as it applies to air conditioning engineering is covered in two sections. Part I covers basic principles; Part 2, on applications and psychrometry, to follow. Subjects covered in Part I include equivalence of various types of mechanical energy; meaning of internal energy and its relation to work and heat; the fact that specific heat depends on the type of process involved; meaning of enthalpy; important characteristics of ideal gases; mixture of ideal gases; and reversibility.

717. Parkinson, B. R. Gas Engr. (Lond.), vol. 47, No. 11, Oct. 1930, pp. 571-573

SOME NOTES ON THE PHYSICAL SIDE OF GAS PRACTICE -- THE PROBLEM OF DEHYDRATION. Amplification of discussion of paper read before Inst. Gas Engrs. by E. W. Smith, previously indexed from various sources; importance of temperature, pressure and condensation in processes of gas manufacture and distribution.

718. Peck, R.E., Ryant, C.J. Refrig. Engng. 56, 417, 1948

CONDITIONING OF HOT HUMID AIR. The object of the investigation was to determine the basic relationships necessary for the design of equipment for conditioning air. Data were obtained by use of Lithium Chloride solution and by a cold surface.

719. Perry, J.H., Duus, H.C. Chem. & Met. Eng. v 41 n 3 March 1934 p. 127-9

ABSORPTION, REFRIGERATION AND COMPRESSION FOR DRYING OF GASES. Comparative costs per 1,000 c.ft.

(1)	Ca Cl_2 brine.	0.037 dollars.
(2)	Refrigeration.	0.009 - 0.013
(3)	Compression.	0.006

(3 includes power for distribution.) Where cost of power is high, no (1) would have advantages.

720. Perry, J. H. Chemical Engineers Handbook, 1950, pp. 877-884

THE DRYING OF GASES. The various methods of drying gases are described. The properties of liquid and solid desiccants are described and tabulated.

721. Pfister, R.J., Kerley, D.J. A.S.T.M. Bull., 127, 17-22, 1944

FUEL GAS. WATER VAPOUR DETERMINATION. An Evelyn photo-electric colorimeter is used with 0.1% Cobaltous Bromide in butanol as reagent. See under "Moisture Determination. General."

722. Pierce, H. C. Mech. Engng, 1945, 67, 171-4, 189

GAS AIR CONDITIONING UNIT. An all-year air conditioner designed to provide heating, humidifying, air cleaning and circulation in winter, and cooling de-humidifying, air cleaning and circulation in summer consists essentially of an indirect steam-heating system, an absorption refrigeration unit, an air-filtering section, and a centrifugal-fan section. The unit contains a gas-fired boiler or steam generator. During the winter cycle, steam is delivered to a heating coil within the fan section of the unit assembly. During the summer cycle steam is delivered to the absorption refrigeration unit also contained within the unit assembly. Any of the functions of complete air conditioning is available, by selection, through a co-ordinated control system. Temperature conditions are automatically maintained as desired. The complete conditioner is compact and requires little space for installation. Models of different capacity will be available. Diagrams, and details of the construction, operation and performance.

723. Pinkl, V. Tonindustrie-Zeitung. vol. 55, No. 57, July 16, 1931, pp. 830-831, 1 fig.
FEHLERHAFT ANGELEGTE LUFTTROCKNEREIEN (FAULTY CONSTRUCTION OF AIR DRYING PLANTS). Anonymous discussion of article previously indexed from issue of May 18, 1931.

724. Pittsburg Lectrodyer Corp.
A dehumidification (U.50) m/c having a renewal capacity of 700 lb. water a day from air at 75°F. Wet bulb. Dual adsorbent dryer with activated Alumina, and is automatic.

725. Pittsburg Lectrodryer Chem. Age. 59, 1520, p. 288, 28.8.1948
(Birlec Ltd., London)
INSTRUMENT AIR DRYER. 150 p.s.i. steam or electric reactivation of Alumina. Up to 5,000 c.ft. min. All automatic.

726. Quarendon, P. Ind. Chemist, 15, 279-86, (1939) July
MODERN METHODS OF GAS DRYING IN CHEMICAL INDUSTRY. A comprehensive review of methods for removing water vapor from gases including absorption in liquids (H_2SO_4, glycerol, $CaCl_2$ brine), adsorption (SiO_2 gel and activated Al_2O_3), and refrigeration. No equipment performance data are included, but (estd. English) cost data are given. References quoted:-

Chem. & Met. Eng. 29, 147, 1923	Whitman.
Ind. Eng. Chem. 12 1291, 1926	Greenewalt.
Gas World 190 738, 1930	Smith.
Gas u. Wasserfach 78 828, 1935	Anderson.
Gas J. 205 809, 1934	Knowles and Summerson.
Foote Prints 8 2.1.1935	Bichowsky.
Gas u. Wasserfach 74 1169, 1931	Lenze
Proc. Amer. Gas. Assoc. 664, 1934	Lednum.
Z.V.D.I. 907, 1926	Krull.
Chem. & Met. Eng. 35 731, 1928	Bragg.

727. Queer, E.R., McLaughlin, E.R. Ind. Heating Engr. 10, 41, 98-100, May, 1948
RATING DYNAMIC DEHUMIDIFICATION EQUIPMENT. Carried out in connection with maintaining a 30% R.H. in submarines.

728. Reid, L. S. Gas, Dec. 1946, 22, 34-37
PERRYVILLE' UNIQUE DEHYDRATION PLANT. SOUTHERN NATURAL GAS CO. INCORPORATES UNUSUAL FEATURES IN AUTOMATIC INSTALLATION. The fundamental design of the Perryville, La. dehydration plant (75,000 Mcf. per day rated capacity at 450 p.s.i.) is quite conventional, for the gas is contacted by a countercurrent flow of 95% diethylene glycol solution to remove the desired quantity of water vapour. However, the process was made fully automatic and foolproof, capable of supervision by a field dispatcher as a part

of his regular duties, providing efficient dehydration at all times regardless of load variations, by simplifying the process, providing automatic controls and alarms and eliminating several less important features usually found in more conventional installations to minimize the initial cost. The principal simplifications are: (1) installation of direct fired reboiler on the fractionator (cheaper, simpler and safer to operate than steam or Dow-therm boiler or oil heater); (2) constant rate of glycol circulation regardless of variations in gas throughput; (3) combination of fractionator feed pre-heater and reboiler, eliminating need for separate units; and (4) operation of the fractionator at atmospheric pressure, eliminating back pressure controls and effecting a saving in fuel.

729. Riebeck, E. W. Goodheart-Wilcox Co., Chicago, 1939
470pp., 3rd. Ed.
AIR CONDITIONING. Fundamental principles, practical installation and ozone facts.

730. Rollman, Walger F. U.S. 2,475,255, July 5, 1949
DRYING GASES. (Standard Oil Development Co.) A gas containing moisture is dried in a 5-stage process, which comprises (1) passing it in an upward direction through a cooling zone containing a body of granular material at a velocity sufficient to keep the granular material is suspension within the gas; (2) maintaining the cooling zone at a temperature below the temperature of the incoming gas and sufficient to freeze the moisture contained in the gas; (3) removing the gas, granular material, and ice particles from the zone; (4) separating the granular material from the gas and ice particles, cooling it, and returning it to the zone; and (5) separating the ice particles from the gas. Sand of 20-50-mesh particle size is suitable for use as the granular material. The motion of the particles prevents collection of frost on the cooling surfaces of the zone.

731. Ruhemann, M. Clarendon Press, Oxford, 1949, 298/1/1
THE SEPARATION OF GASES.

732. Ruheman, M. Chemical Engineering Convention,
Inst. Chem. Eng. Apr. 1951
THE LOW TEMPERATURE INDUSTRIES. A whole field of investigation into the drying and the dryers for gases to dew points -60° - 80°F. Usually, solid adsorbents, Alumina. but the Elliot process (Amer.) uses regenerators. Plates over which the gas passes at -180°C and the higher pressure gas (5 times pressure) passes in the reverse direction and deposits moisture. Periodical thawing out is largely avoided or abolished. But periodic thawing out may be a good thing to get rid of C_2H_2. Some U.S.A. plants never thaw out.

733. Russell, G. F. Petrol.Refin.Apr.1945, 24, 139-42
DEHYDRATION OF NATURAL GAS WITH DIETHYLENE GLYCOL. The optimum operating conditions of a dehydration plant using diethylene glycol are considered and the basis of the process discussed. The problem resolves into (a) reducing the dew-point to below that which is likely to be encountered by the gas and (b) reducing solvent loss to a minimum. The best means of satisfying these requirements is outlined.

734. Russell, G.F., Thompson, R., Petrol.Tech.Jan.1945; Gas, Apr.1945,
Vance, F.P., Huntington, R.L. 21, No.4, 51
EXPERIMENTAL DETERMINATIONS OF WATER VAPOUR CONTENT OF A NATURAL GAS UP TO 2,000 POUNDS PRESSURE. With the advent of higher pressures in the operation of natural-gas transmission lines, the removal of water from the gas has become increasingly important in order to prevent condensation or formation of gas hydrate from slowing down or stopping the flow of gas. Intelligent design of gas-drying plants has been hampered through the lack of experimental data on the water vapour content of natural gas at elevated pressures. Experimental results were obtained on the water-vapour content of natural gas up to 2,000 lb. per sq. in. at atmospheric temperatures by the Southern Natural Gas Co. The water vapour content at 2,000 lb. is approximately two-thirds as much as it is at 1,000 lb. Deviations from the ideal gas laws vary directly with pressure and indirectly with temperature.

735. Sachs, E. Arch.Warmewirt, 12, 201-4 (1931)
GAS DEHYDRATION TECHNOLOGY.

736. Saunders & Taylor Ltd., B.P.588,839 of 10/8/1945:27/5/1948
Hindley, A.
AIR-CONDITIONING APPARATUS. An air-conditioning unit (for textile laboratories, small hospital wards, etc.) comprises a casing with air inlet and exit apertures, means at the end for drawing air in and circulating it through the casing, an electrically-heated water tank with water level and temperature controls and means for deflecting the air on to the surface of the water.

737. Schroth, W., Konrad, W. Gas- u Wasserfach v 79 n 7 Feb.15, 1936
p.97-103
UEBER GASTROCKNUNG. Purpose and advantages of drying of gas; outline of drying process and description of equipment used; cost data.

738. Schroth, W., Konrad, W. Gas Age-Rec. v 78 n 13 Sept.26, 1936,
p.339-43
GAS DEHYDRATION. Abstract translation of paper previously indexed from Gas- u. Wasserfach Feb. 15 1936.

739. Sedgwick, D. L. Gas Age, 17 Apr. 1947, 99, 39-39
AUTOMATIC DEHYDRATION OF LARGE VOLUME OF GAS AT HIGH PRESSURE. A quantitative flow sheet for the dehydration of natural gas by glycol is presented. The plant was designed by the Dresser Engineering Co. Auxiliaries are indicated on the flow sheet and some plant data are stated.

740. Senatoroff, N. K. Gas, June, 1945, 21, No. 6, 25-6, 28, 30, 33-4, 37
DEHYDRATION (OF NATURAL GAS) AT HIGH PRESSURE USING DIETHYLENE GLYCOL WATER SOLUTION. This paper presents an outline of the computations which it was necessary for the designing engineer to go through in order to be able to write up a set of specifications covering important structural details of the water vapour absorption equipment, fabricated to operate at pressures exceeding 1,000 psig. It is felt that methods employed in deriving basic data or in correlating the information already published elsewhere might prove useful to the operating engineer directly connected with the supervision of dehydration plants. Attached to the paper are several curves which are collected together for convenience.

741. Senatoroff, N. K. Oil Gas J., 15 Dec. 1945, 44, (32), 98
APPLICATION OF DIETHYLENE GLYCOL-WATER SOLUTION FOR DEHYDRATION OF NATURAL GAS. Diethylene glycol has proved to be a very satisfactory substitute for the calcium chloride previously employed for dehydration of natural gas, and has the advantage of being less corrosive than the latter. The paper presents some of the process engineers' basic computations pertaining to the design of suitable equipment. The application of diethylene glycol solution to dehydration of natural gas at operating pressures in excess of 1,000 lb./sq. in. was recently tried on the Pacific coast in connexion with the Goleta-Ventura natural gas transmission line, but rigorous engineering design of absorption equipment was impossible owing to complete lack of data on the properties of glycol solution at this high pressure. It was therefore decided to limit design computations to purely theoretical studies of the effect of increased operating pressure on the important phases of the absorption process, taking as a basis some data obtained from a similar plant working at 400 lb./sq. in. Examples of the calculations are given, with detailed information as to the properties of ethylene glycol in solution and the saturate water-vapour content of natural gas. Drawings of the absorbers and bubble caps employed are included, and consideration given to factor such as absorber diameter, effect of pressure on absorption rate, plate spacing, and number of plates used. A bibliography is includ

742. Sherwood, T. K. McGraw Hill Co., 1937 International Serie of Pure and Applied Physics
THE DRYING OF GASES. ABSORBTION AND EXTRACTION. A theoretical treatment including the "Two Film Theory .

743. Short, E. H. Oil Gas J., 12 Apr. 1947, 45, (49), 82-3
GAS DEHYDRATION AT PECAN ISLAND. In the Pecan Island gas field, Humble Oil & Refining Co. recently completed a modern gas-dehydration plant. At present the volume of gas dehydrated by the plant ranges from 15 to 40 million cubic feet per day. Removal of the water from the gas is accomplished by bringing the gas into contact with diethylene glycol. Gas enters a contractor at its base from a 10-in. wet-gas header and goes through a scrubber in the bottom of the contactor which scrubs the gas of free water and condensate. The gas passes upward through a chimney plate and thence through standard bubble-cap plates where it contacts the solution. In the third stage the gas enters a second scrubber located in the top of the contactor shell. Traces of glycol are scrubbed out and the gas is delivered to the pipe line through the outlet dry-gas header.

744. Short, E. H. Oil Gas J., 13 Sept. 1947, 46, 88-89
COMPACT PLANT DEHYDRATES GAS AND METERS DISTILLATE. For some time Continental Oil Co. has had in operation in southwestern Louisiana several compact dehydration and metering plants. Typical of these plants is on the lease of the H. M. Naylor Oil Co. in the West Mermentau field. This plant is handling approximately 14,000,000 cu. ft. of gas per day from 3 Naylor wells and 14 Continental wells. Pictures of the important installations in the plant with a brief description of their operations are given.

745. Smith, G. F. Journal of Soc Chem. Ind., Vol. 53, No. 17, April 1934, p. 357
IMPROVED DEHYDRATION OF AIR FOR USE IN THE MANUFACTURE OF HIGH PRESSURE TANK OXYGEN USING ANHYDROUS MAGNESIUM PERCHLORATE.

746. Smith, H. C. Gas Engr. 48, 203-6 (1931) Apr.
DRI-GAS AND NAPHTHALENE WASHING PLANT. Economics of process.

747. Solvay et Cie (Soc.) Chimie et Industrie 38 3-12 July 1937
DRYING GASES BY CALCIUM CHLORIDE. See also Chem. Age. 39 428 May 1938.

748. Sperr, Jr., F. W. Am. Gas. Assoc. Proc. 1250 (1926)
GAS DEHYDRATION. Thorough-going discussion of various possible methods of drying city gas. Bib., includes articles on drying air.

749. Strock, C. Heating and Ventilating's Data Book. 1948 Industrial Press, New York
Section 1-57pp. Heat and Moisture in Air. 30 pages of psychrometric tables and charts.

750. Sturtevant Engineering Co., Ltd. Textile Weekly, 1949, 43, 1234-1238

NYLON FACTORY AIR-CONDITIONING PLANT. An illustrated account is given of the air-conditioning equipment of the British Nylon Spinners' factory at Pontypool. The total floor space of the factory is 1 million sq. ft. and the total volume of conditioned air delivered is about 4½ million cub. ft. per minute.

751. Tanzola, W. A. Southern Pwr. and Industr., Feb. 1946, 64, 60-63

AIR CONDITIONING SYSTEMS AND THEIR CHEMICAL TREATMENT. A review of problems arising in connection with cooling water and spray water of air conditioning systems. The chief problem is the proper treatment of the water to insure against scale formation, corrosion, and the fouling of heat transfer surfaces by organic growths. Appropriate chemical treatment to prevent each of these troubles is suggested.

752. Weber, G. Oil Gas J., 1 July 1948, Vol. 47, 63, 70

COMPRESSION, DEHYDRATION PLANT PROVIDES FULL GAS UTILIZATION. About 1 M.M. c.f./day of low pressure casinghead gas and about 10 M.M.c.f./day of high pressure gas is processed in a compression-dehydration plant. The plant is connected to 64 oil wells nearly all of which are on gas left by a nine mile gathering system and to high pressure gas wells by a four and one half mile gathering system. After compression and scrubbing the casing-head gas is mixed with the prime gas from an inlet separator and sent to the dehydrators. Dehydration to not more than seven lbs. of water per M.M.c.f. is accomplished with granular dessicant. The drying agent has been regenerated by hot gas on alternate days for two and one half years without loss of activity. Both gas streams treated are very lean (about one half gallon of liquids per M.c.f.) so that an absorption plant would not be economical. Liquids are recovered at the separators, between stages of compression and from the dehydration system.

753. Webster, T. J. J.S.C.I. 69, (11), 343-5 Nov. 1950

THE EFFECT ON WATER VAPOUR PRESSURE OF SUPERIMPOSED AIR PRESSURE. In a compressed gas, saturated with water vapour, the v.p. of the water exceeds the amount predicted by Poyntings Thermodynamic relationship.

The experimental work and quantitative aspects are discussed. Diagrams and Curves.

754. Weisselberg, A. Chem. & Met. Eng., 45 418-21, 1938

CHEMICAL DEHUMIDIFICATION OF AIR. Excellent use of this method in the drying of leather and other articles.

755. Weitzel, H. R. Gas Age 102, (7) 77, 120-24 30 Sept. 1948
Combination Scrubbing, Dehydration and Desulphurisation Plant. (For natural gas.)

756. Wells, J., Wade, L. G. Chem. & Met. Eng. 39, 146-9 1932
DRYING AND AIR CONDITIONING IN CABLE MANUFACTURE. A room is maintained at 0.5% R.H. at 110-115°F. Flow sheet.

757. Whitehead, M. H. Nat. Gas Bull. Australia, July-Aug. 1947, 11, 14-17
TOWN GAS DEHYDRATION. The water vapour in town gas (usually saturated at the distribution temperature and pressure) gives rise to serious problems in deposition of water and corrosion in underground pipes. Serious thought is given to the partial dehydration of the distributed gas to a dew point at least 5° below the lowest distribution temperature. This could be accomplished by refrigeration, compression and subsequent cooling, absorption by solutions whose vapour pressure is lowered by suitable solutes as $CaCl_2$ or glycerin and adsorption on the surface of activated agents. Re-absorption of water vapour in a water-sealed gas holder is prevented by introducing a film of oil over the holder water. It is believed the advantages gained would off-set the additional cost of dehydration. Advantages and disadvantages are summarized.

758. Wikoff, A. G. Chem. & Met. Eng. 30, 181-4, 1924
OXYGEN BY THE LIQUEFACTION PROCESS. The residual moisture after compression is removed by steel cylinders of caustic potash lumps of walnut size, in series, which can be exchanged when spent, without interrupting the process.

759. Williams, G. A. Mech. Wld, 1946, -120, 513-516
ACTIVATED ALUMINA. The use of activated alumina is discussed with reference to drying of air and gases. Among the illustrations of plant is one of an air-conditioning plant.

760. Various Authors Chem. & Met. Eng. 47, 285-332, May 1940
CONDITIONING OF GASES AND AIR SYMPOSIUM. Use of Psychrometric Principles.-Barta. Garber. Air-Solvent Vapour Psychrometric Charts. - Types of Psychrometric Charts.

Othmer Psychrometric Chart - Othmer
Condensation by Refrigeration - Hunter
Absorbent Solutions - Bichowsky
Lithium Chloride - -
Calcium Chloride - -
Activated Carbon Absorption - Mantell
Silica Gel Absorption - Dehler
Activated Alumina Absorption - Simpson
Other Dehydration Methods - -
Choice of Dehydration Methods - Patterson
Humidification Processes - -
Compression Equipment - Deutsch
Heat Transfer Surfaces - Ashley
Gas Cleaning Equipment - -
Liquid Gas Contactors - Johnstone
Air Conditioning - -
Recovery of Solvent Vapours - Ray
Drying Psychrometry - -

ADDENDUM

761. ---- Ceramics 2 278, 1950
FIELDEN ELECTRONIC HYGROMETER. Suitable for measuring the water content of flue gases etc. Immediate and continuous indication of R.H. in the range 40-100% at temperatures up to 200°F with an accuracy of 1%.

762. Aitchison, G.D., Butler, P.F., Gurr, C.G. Australian Jnl. of Science 2, 1, 56-75, March, 1951
TECHNIQUES ASSOCIATED WITH THE USE OF GYPSUM BLOCK SOIL MOISTURE METERS.

763. Arnold, J. H., M.I.T. Physics 4, 1933
THE THEORY OF THE PSYCHROMETER. I. 255-262. The Mechanism of Evaporation. II. 334-340. The Effect of Velocity. The correct theory consists of a combination of the two older theories of Maxwell and August.

764. Ciborowski, J., Tuszinski, K. Przem. Chem. 29, 343-354, 1950, (VI)
MASS TRANSPORT IN THE DRYING AND HUMIDIFICATION OF GASES.

765. Dryden, H. C. Ind. & Eng. Chem. 31, 416-425, 1939
TURBULENCE AND DIFFUSION. Modern developments in the experimental and theoretical aspects of turbulence in relation to the process of diffusion are reviewed. The work of Reynolds, Taylor and von Karman are connected.

766. Garber, H. J., Licht, W. Industr. & Eng. Chem. 38, 7, 757-759, 1946
NOMOGRAPH FOR CALCULATION OF OVER-ALL HEAT TRANSFER COEFFICIENTS.

767. Griffiths, E. Advancement of Science 7, 28, 31, 1951
THE UNIT OF HEAT. The Royal Society has issued a leaflet "The Unit of Heat" recommending the use of the Joule (10^7 ergs.) as the fundamental unit, October, 1951. A conversion table for the various calories is given. The present note gives a short review of the efforts made over the last 55 years towards acceptance of an absolute unit. It also emphasises the importance of defining calories in terms of joules when calories are used. Abstr. in J. Inst. Mech. Engrs. Apr. 1951.

768. Henley, A. T. Heat and Vent. Engr. 24, 283, 278-284, Jan. 195
GRAPHICAL SOLUTION OF AIR CONDITIONING AND DRYING PROBLEMS.

769. Hickman, M. J., N.P.L. D.S.I.R./7001/C, July, 1951
EXPERIMENTAL INSTRUMENTATION FOR DRYERS. Instruments used for measurements on commercial conveyor belt and tray type dryers during experimental testing are described, and the improvements in operation of the dryers resulting from the experiments are discussed.

770. Hooper, F. C., Lepper, F. R. Heat. Pip. and Air Cond. 22, 129-134, Aug. 1950
TRANSIENT HEAT FLOW APPARATUS FOR DETERMINATION OF THERMAL CONDUCTIVITIES. Description of electrically heated probe for determining within 10 minutes the thermal conductivity of wet or dry solids. Precision measurement. Mathematical theory is developed. B.E.A.

771. Lane, A. M. Amer. Soc. Mech. Engrs. Paper, April, 1951
DRYING AND ATMOSPHERIC AIR POLLUTION.

772. Lorenz, H. Zeitschr. f. Techn. Physick, 15, 4, [illegible]
CONTRIBUTION TO THE PROBLEM OF HEAT TRANSFER IN A TURBULENT STREAM. An examination of the factors affecting heat transfer.

773. Martin, S. B. S. I. R. A., Rsh. Rep. Index No. R. 147
D. S. I. R 5620/b, 1951
THE MEASUREMENT OF RELATIVE HUMIDITY BY AN ELECTRICAL METHOD UTILISING ADSORPTION IN CERAMIC ELEMENTS. Progress Report.

774. Middlebrook, G. B., Piret, E. L. Ind. & Eng. Chem. 42, 1511-13, 1950
HOT WIRE ANEMOMETRY. A hot wire anemometer can be used for very low rates of flow especially near walls. Bubble formation can be avoided by coating the wire with resin or by using a very short wire. B. C. U. R. A.

775. Nusselt, W. Zeit. f. Ang. Math. u. Mechanik. 10, 2, 105-121, 1930
HEAT TRANSFER, DIFFUSION AND EVAPORATION.

776. Perry, J. H. Chemical Engineers Hand-book, 1950, Sect. 12, pp. 757-797
HUMIDIFICATION, DEHUMIDIFICATION COOLING TOWERS AND SPRAY PONDS. Psychrometric tables and charts. Thermodynamic properties of water at saturation. Air conditioning, humidity controlling devices.

777. Rollman, W. F., U. S. P. 2, 475, 255, 1944-1949
Standard Oil Dev. Co.
DRYING OF GASES. Gas is mixed in a cooling zone with a suspended granular material, e.g. sand; and the ice crystals and sand separated from the gas subsequently.

778. Sherwood, T. K. Ind. & Eng. Chem. 42, 2077-2084, 1950, B. I. 165, Feb. 1951
HEAT TRANSFER, MASS TRANSFER AND FLUID FRICTION. Typical experimental data on vaporisation from plates and spheres into turbulent air streams are compared with theories of the over-all transfer process from a turbulent stream to a pipe wall in order to demonstrate their essential similarity.

779. Sherwood, T. K. Chemistry in Canada 2, 6, 87-90, 1950
CURIOUS HISTORY OF THE WET BULB HYGROMETER. The development of a theory of the wet bulb thermometer and its application to problems in the design of cooling towers, air-conditioning plant, etc. are discussed. That wet bulb temperatures are the same as the calculated temperatures of adiabatic saturation for the system

air-water is a pure coincidence, due to the fact that the thermal conductivity of air and the diffusivity of water vapour in air are such that the ratio between the coefficient of heat transfer, air to wet surface and the coefficient of heat transfer, wick to air is about 0.25, which is equal to that of the value of the heat capacity for most air-water mixtures.

780. Sherwood, T. K., Woertz, B. B. Ind. & Eng. Chem. 31, 1034-1041, 1939

MASS TRANSFER BETWEEN PHASES. Role of eddy diffusion. The work represents a study of the relative importance of molecular diffusion through the laminar surface film and of eddy diffusion in the main body of the turbulent fluid for the case of vaporisation of water into a turbulent gas.

781. Towle, W. L., Sherwood, T. K., Suder, L. A. Ind. & Eng. Chem. 31, 457-463, 1939

EDDY DIFFUSION. Mass transfer in the central portion of a turbulent air stream. · Effect of a screen grid on the turbulence of an air stream.

782. Luikov, A. V. Gos. Moskva-Leningrad 1950

Teoriya Sushki. (The theory of drying). 416 pp. Br. Museum Library.

783. Nicol, D. L., U.C. Ldn. Industr. Chem. 27, 319, 339-344, Aug. 1951

DRYING GRANULAR SOLIDS BY HIGH FREQUENCY CURRENTS. A study of the behaviour of water and salt solutions when heated by H.F. currents, and the moisture distribution in a bed of partially dry material such as glass beads or sand. Relations between all variables are presented graphically, and the mechanism of drying is suggested.

SECTION 2

DRYING PROCESSES AND EQUIPMENT
DRYING GENERAL

1. Various Authors Trans.Inst.Chem.Eng. 6 1928

CONFERENCE ON DRYING.

The Seasoning of Timber	Stillwell
Tunnel and Stove Drying	Henley
Film and Spray Drying	Reavell
Drying by Pressure	Hinchley
Rotary Dryers	Horgan

See under separate headings and authors.

2. Various Authors Ind.Eng.Chem. Symposium, 30 (9) 1938

		Page
MACHINERY FOR DRYING	F. Kershaw	1115
Drying Air and Commercial Gases with Activated Alumina	B. Derr	384
Tray Drying. Evaporation of surface moisture.	C. B. Shepherd C. Hadlock, R. C. Bower	388
Evaporation rates from wet material and a free water surface.	A. E. Stacey	1385
Fundamental Principles	E. R. Gilliland	506
Commercial Drying of Solids	R. C. Ernst, D. B. Ardern, A. K. Schmied, F. M. Tiller.	1119
Spray Drying	B. B. Fogler, R. V. Kleinschmidt	1372
Evaporation into quiet air from a 1 foot diameter. surface	B. F. Sharpley, L. M. K. Boelter	1125
Air conditioning equipment	M. Ingels	980
Aeroform Dryer	O. A. Hurxthal	1004
Drum Drying.	D. J. Van Marle	1006
Filter Drying	D. F. Irvin	1002
Rotary Dryers	B. A. Smith	993
Rotary Steam Tube Dryer	C. E. Bill	997
Rotary Vacuum Drying	L. H. Bailey	1008
Roto-Louvre Dryer	J. L. Erisman	996
Spray Drying	W. S. Bowen	1001
Vertical Turbo-Dryers	A. Weisselberg	999
Evaporation from free water surface by perpendicular air stream.	M. C. Molsted, C. Faareweg, J. A. Farrel	1131

3. Anon. Ind.Chem. 7, 121, 156, 1931

CHEMICAL ENGINEERING CHARTS. NOS. 1 AND 2. (1) Drying tunnels and chambers, steam heated. (2) Influence of variation in air temperature and velocity on rate of evaporation.

4. See under COAL.
Drying by Fleissner Process
Drying by Organic Liquids.

5. ---- Invest. V.T.I, 15 (9/10) 51, C.A. 41, 2286, 1947
DRYING TECHNIQUES. A review of drying practices in U.S.S.R.

6. Anon. Brit. Claywkr., 52, 86, 1943
OVER-KILN DRYING. The drying of goods above the kiln is discussed and longitudinal and cross-sections of such a kiln and dryer are depicted.

7. Anon. Chem. Ztg. 56, 136-7, Feb. 17, 1932
EVAPORATION AND DRYING OF HEAT SENSITIVE SUBSTANCES.
The Herbert System. (Herbert, Lahr, Baden) uses steam under vacuum for heat supply rather than hot water.

8. ---- Ind. Heat Eng. 6 3-7, 1944
USE OF STEAM IN A DEHYDRATION FACTORY.

9. Anon. Chem. Age. 60 1541 p. 153 Jan. 1949
INDUSTRIAL DRYING PROCESSES. This is a review of Chamber's, McTaggart' and Stephen's papers read at the Inst. of Chem. Engrs. 11 Jan., 1949.

10. Anon. Chem. Ind. 64 (2) 258, Feb. 1949
RECIRCULATING AIR IN GAS DRYER OBVIATES DANGER FROM FREEZING AND PERMITS YEAR-ROUND OUTDOOR INSTALLATION. DIAGRAM AND PHOTOGRAPH.

11. Anon. Industrial Chemist 7 121, 1931
156, 1931
1. A chart relating steam requirements, temperature, humidity, quantity of air, for tunnel and chamber dryers. Based on practical data. 2. A chart to shew the relation between variation in air temperature and air velocity on rate of evaporation in drying tunnels and chambers.

12. ---- Food. April, 1950 pp. 139-142
Three million tons of water are imported annually with food'stuffs. This weight could be reduced by 80%.

13. ---- U.S. Dept. of Agric. Misc. Publ. 540, 1944
Theory underlying dehydration (and types of dryers).

14. —— Ind. Chemist IV 512 Dec. 1928
Trans. Inst. Chem. Engrs: Vol. 6, 1928

Conference on Drying. Dec. 6-7. Short Abstracts:-

Reavell	Film and Spray Dryers
Hinchley	Pressure Drying
Stillwell	Seasoning or Drying of Timber
Riley	Vacuum Dryers
Henley	Tunnel and Stove Drying.

15. Anon. Industr. Gas., Dec. 1945, 24, 15

DEHYDRATING APPLE NUGGETS. A brief description of the dehydrating plant of the Naman-Krum Co. is given. Natural gas is used in firing two large boilers which furnish the steam for a huge rotary drier and also in firing a third boiler which provides the hot water to heat five vacuum driers. Natural gas is preferred on account of the following advantages: (1) begins to function at top efficiency the instant it is turned on, (2) it is economical, (3) easy to operate and regulate: (4) it is a clean fuel, and (5) it assures the most uniform heat.

16. Anon. Power, 1945, 89, No. 1, 77; No. 2, 100; Steam Engr, 1945, 45, 317

SURE-FIRE FORMS FOR COMBUSTION CALCULATION. I. SOLID AND LIQUID FUELS. II. GASEOUS FUELS. Convenient standard forms for calculations relating to the combustion of solid liquid, and gaseous fuels are presented in these articles, with worked examples of their use. The forms provide spaces for the entry of the ultimate analysis of the fuel, and tables which are then completed by simple calculations in the order set out and using constants which are printed on the form. The possibility of mistakes is virtually eliminated and values can be rapidly determined for the theoretical air, theoretical CO_2 and actual CO_2 percentages for various percentages of excess air.

17. Allerton J. Microfilm Abstr. 8 No. 2, 28, 1948 (B. 1. 166, Feb. 1950) Ann Arbour. Mich. Univ.

THROUGH DRYING OF POROUS MEDIA. Rate of vaporisation of water from a porous bed in an air stream has been investigated with glass balls, crushed quartz and mixtures. There are 2 periods. A maximum steady rate where air becomes saturated, vaporisation occurring from a narrow zone which gradually moves down the bed leaving a dry bed above. When this reaches the bottom, the falling rate begins. Mathematical expressions are given for this stage. The thickness of the bed does not influence the drying rate with small pressure drops.

18. Allerton, J. Brownell, L. E. Katz, D. L. — Chem.Eng.Progr. 45 (10) 619-635 Oct.49

THROUGH DRYING OF POROUS MEDIA. The object of the investigation was to study the basic mechanism and to measure experimental rates of the drying of filter cakes. Through-drying in the passing of air through the medium. Experiments on porous beds of uniform glass balls, crushed quartz and one binary mixture of glass balls. Two periods, maximum and decreasing rates. Description of apparatus. The treatment is mainly mathematical, the purpose being to establish fundamental relationships necessary to permit calculations for drying when using filters and similar equipment.

19. Alliott E. A. Chigison S. C. — Trans.Inst.Chem.Engrs.2 93-110 1924

BIBLIOGRAPHY. A classified compilation of some 500 annoted references to the literature prior to 1924.

20. [illegible], E. B. Borkland, R. A. — Chem. & Met.Eng.[illegible], 1923 [illegible]

DRYING. Data on pan drier, drying sand, coal, sawdust, fireclay, gypsum.

21. Antoni, A. — Chaleur & Industrie v 16 n 177 Jan.1935 p. 29-48

LE SECHAGE INDUSTRIEL. Industrial drying; outline of various processes and equipment; some mathematical analysis.

22. Bárta, R. — Industr.Céram.,1947,No.375,196

CONDITIONS FOR CORRECT RAPID DRYING. It is the aim of a drying technique to accelerate the expulsion of moisture from the centre to the outside of an object, and to ensure that, no phase of the drying process is needlessly prolonged. Reference is made to a number of attempts to achieve this acceleration, including drying under vacuum, humidity drying, high-frequency induction and drying under pressure between heated porous disks. Humidity drying consists essentially of pre-heating the moist products, primary drying, and final drying. The first phase sets up a movement of moisture towards the surface, contraction starts in the second phase, and in the final drying the temperature can be raised considerably without damage to the goods.

23. Becker, R. — Chem. & Met.Eng.28 94 1931

INDUSTRIAL DRYING. General Survey of Drying in Chem. Plants.

24. Boic, V.

DRYING BY EVAPORATOR CONDENSATE. See under "COAL".

24. Badger, McCabe McGraw Hill 1936 2nd Ed.
ELEMENTS OF CHEMICAL ENGINEERING CHAP. VI p.239. DEALS WITH DIFFUSION.

25. Brown Boveri & Co. B.P.548,131 1942
IMPROVEMENTS IN DRYING APPARATUS WITH HEAT RECUPERATION. The moisture laden vapour from the first drying section is passed through a heat exchanger where part of the latent heat is recovered in heating air for the second drying section.

26. Brownell, L. E. Chem.Engng. 56 (9)(10).112-15 Sept.and
Crozier, H. E. 124-7 Oct.1949
BLOWER AND HEAT REQUIREMENTS OF ROTARY DRUM AND VACUUM FILTER DRYERS. An analysis of flow through porous beds; Allerton's data are used and the drying of sand used as an example.

27. Brownell, E. Katz, D.L. Chem.Eng.Progress.(Trans.Amer.Inst.Chem. Eng.),1947,43,703-712
POROUS MEDIA: FLUID FLOW THROUGH: APPLICATION TO ROTARY VACUUM FILTRATION. General correlations developed for single-phase flow through porous media and for simultaneous flow of two homogeneous phases (see Summary, 1947, p.554) are applied to the cycle of a rotary vacuum filter. "Unsteady" states resulting from changing cake thickness during deposition and from changing effective saturation during air flow necessitate integration of the "steady" state relations previously presented. Graphical integration methods may be used for either turbulent or laminar flow. Formal integration methods for predicting cake deposition are used when flow is known to be laminar. An example problem is given in order to demonstrate the use of the equations for computing filtrate removal and air flow through cake, resistance of filter media, washing, drying, and crystallisation, are briefly discussed. There are 27 references to the literature.

28. Carne, T. W. J.Am.Ceram.Soc.,16,118-23 (1933)
MODERN WASTE-HEAT TUNNEL DRYERS. Use of dryers utilizing all waste heat available from kiln firing and cooling.

29. Carrier Engrg. Corp., Newark, N.J. (1929)
DRYING AND PROCESSING OF MATERIALS BY MEANS OF CONDITIONED AIR.

30. Carrier and Stacey Ind.Eng.Chem.13 438 1921
THE COMPARTMENT DRIER. Condensing water before blowing air into the drying chamber.

31. Cash, M. G. Mod.Engng.1947 21 p.19 1.Jan.
Br.Cast Iron R. A.
AIR HAS MANY USES:- DRYING IN A FACTORY.

32. Chamberlain Textile World, 1933 83 1965
EXTRACTING AND DRYING FROM THE CHEMICAL ENGINEERING STANDPOINT.

33. Clegg, R. R. Pap. Mfrs. Assn. G. B. Proc. Tech. Sect. 25 104-174. 1945
DRYERS AND DRYING. Principles discussed. Equipment well illustrated.

34. Clegg, R. R. Mech. World. 119 248-52. 1946
DRYING BY HOT AIR. Paper to the Institute of H. & V. Engineers. Deals with constant and falling rate periods.

35. Clegg, R. R. Paper. Inst. of Fuel. 30 Jan. 1951 Chem. Tr. Jnl. 128 (3323-4) p.333-4. 9 Feb. and p.382-3 16 Feb. 1951
DRYING TECHNIQUE. Survey of the main types of drying equipment in current use. Brief examination of the relative merits of direct and indirect heating. 32 diagrams.

35a. Fabricius, W. V.D.I. Verlag. Berlin 1933. 42 pp.
DIE BERECHNUNG DER TROCKENDAUER, illus., diagrs., charts, 2.50 rm.

36. Ferre, A. W. Ind. Heating 1944, 11, 262-72, 428-33, 774-84, 1126-41; Chem. Abst. 1944, 38, 6139
INDUSTRIAL DRIERS AND DRYING SYSTEMS. The fundamentals of drying at atm. pressure and various drying methods for industrial products are discussed.

37. Fisher, E. A. Trans. S. C. I. 1935 54 343T
SOME FUNDAMENTAL PRINCIPLES OF DRYING. Theoretical Aspects are discussed. (a) external factors, temperature and humidity of the drying atmosphere; effective velocity of air over heating stack; heat supply; (b) internal factors: chem. and phys. nature of material; changes during drying.

38. Franklin, C. E. L. Br. Pottery and Ceramic R.A. Technical Papers 1947 and 1949
THE EFFICIENCY OF DRYERS FOR EARTHENWARE.
See under Ceramics.

39. Friedman, S. J. Ind. Eng. Chem. 38 22-3. Jan 1946
DRYING. A review of the papers published in 1944 and 1945 on the practical and theoretical aspects of industrial drying. 111 Refs.

40. Friedman, S. J. Ind.Eng.Chem.,39,20,1947
DRYING. Last year the literature on drying dealt largely with the newer types of drying techniques. Drying by sublimation is expensive and only applicable to a few expensive products sensitive to heat which cannot be dried by other methods. Few new developments have taken place in infra-red drying technique, which in the ceramic industry has been applied to plates, cups, bath tubs and small refractory articles. Granular alumina and silica heated in a dielectric field of 10-30 M-cycles showed that the heating rate increased with increasing size of granules, but with silica above 3.5 mm. dia. no further increase was obtained. Increasing the dielectric constants of the medium surrounding the particles also increased their heating rate. The prediction of the critical moisture content of clays dried by forced convection has been discussed, and on the assumption of a parabolic moisture gradient in the material during drying in the constant rate periods, an equation was derived relating the critical moisture content to the surface critical moisture, the thickness and density of the material, the constant drying rate, and the diffusion coefficient of water in the solid. An equation has also been developed expressing the minimum initial radius of capillaries that can exist in a material without collapse during complete drying. The calculation of the size of continuous dryers for adsorbent materials was also treated. The rate of evaporation of droplets and the investigation of free evaporation into air of gases through very fine porous media are related problems which have also received attention. The article reviews developments in all fields of drying during 1945, and a very full bibliography is attached. 94 Refs.

41. Friedman, S. J. Industr.Engng Chem.,Jan.1948,vol.40,18-22
DRYING. A review of papers published in 1947 on drying techniques, including infra-red, dielectric and sublimation. 163 Refs.

42. Friedman, S. J. Industr.Engng.Chem.,41,27,1949
DRYING. In this review of the 1948 literature on drying it is stated that emphasis has been on minor changes and adaptations or improvements to existing drying methods; little has been presented in the way of new concepts or fundamental information. Infra-red drying received most attention but has been dealt with superficially; an analysis of the effects of radiant heat transfer has shown that the most efficient utilization of any infra-red heating equipment is by combining convection heating with radiant heating. Film properties of enamels baked by infra-red or convection heating were identical when the heating schedules were alike. Some experiments on the baking of foundry cores by dielectric heating showed promise on account of the small space required and the rapid baking obtained. A review of the ceramic field covered hot-floor drying, waste-heat drying, combined gas-fired radiant heat and convection kilns, and kiln construction. Some experimental work was done on the effect of

low-fired grogs on the properties of soft-mud bricks; faster drying and accelerated firing were claimed for certain compositions and grogs. Some pneumatic conveying drying systems have been described and their use for sand drying. The installation of cement kilns over 300 ft. long was reported and claims were made for lower operating costs. Several contributions dealt with the rate of diffusion of water through a material being dried, equilibrium moisture content, and swelling and shrinkage of substances as affected by moisture content. 178 Refs.

43. Friedman, S. J. Ind.Eng.Chem. 42 38-42 Jan.1950 43 73-73 Jan.1951
DRYING. A review of the literature published during 1949-50 on all aspects of drying. 237 and 185 Refs. respectively.

43a. Inst. of Fuel Symp.1948 Leonard Hill Ltd. 383 pp.1948
WASTE HEAT RECOVERY FROM INDUSTRIAL FURNACES.

44. Matthew Hall & Co. London Library Catalogue
Includes 15 American Periodicals.

45. Hausbrand, E. Scott Greenwood & Sons 1924. Transl. from German by A. C. Wright
DRYING BY MEANS OF AIR AND STEAM. Principles of Drying and Tables of data for air, heat and steam consumption. 79 pp.
The original German edition, 1920, 185 pages, contains 6 figures, 9 charts, 35 tables and numerous examples. Publ. by Springer, Berlin.

46. Hirsch, M. 2nd ed. Berlin, J. Springer, 1932. 484p., illus., diagrs., charts, tables
DIE TROCKENTECHNIK. Description of scientific principles of drying process, and machinery for carrying them out; theory of drying and scientific data available to designer; methods and machines in use and their application to different materials, meats, grains, paper, etc.

47. Humphreys, F. E. Can.Chem. & Met. 19, 26 (1935) April
DRYING.

48. Hurxthal, A.C. (Procter & Schwartz) Ind.Engg.Chem. 30 (9) 1004-5 1938
AEROFORM DRYER. An illustrated description of equipment. The pasty material is spread on to a fluted steam heated drum where it attains sufficient rigidity in 20 to 60 seconds to be removed in pieces by tines, the pieces falling on to a close mesh screen which conveys the material through a drying tunnel in 20-30 minutes, hot air being blown through the material.
No other data except steam pressures.

49. Irvin, D. F. Ind.Eng.Chem. 30 (9) 1002-3.1938
Oliver United Filters N. Y.
FILTER DRYING. The process of drying materials such as common salt is described and illustrated. The salt is fed wet on to an endless band of 50 mesh wire screen, hot air from a furnace is sucked through the salt, which can be dried to 0.1% moisture in about 180 seconds. Operating data and overall costs are given.

50. Kamei, S. Sedohara, T. Soc.Chem.Ind.Japan J. V 36 n 12 Dec.1933 p.1561-74
UNTERSUCHUNG UEBER DIE TROCKNUNG FESTER STOFFE- I AND II. See also German abstract in supplement binding of same issue, p.6458.

51. Karpinski, J. Papier.Darmstadt 2 364-371 1948
DRYING BY MEANS OF HOT AIR. All drying processes based on hot air can be followed readily on the Mollier diagram. The heat from used air can only be utilisable in circulation if heat transfer is unaccompanied by moisture. The employment of used air is necessary even if no heat recovery is obtained, if the air velocity necessary for evaporation cannot be attained in any other way.

52. Kiesskalt, S. Mech.Eng. 56, 301-2 (1934) May
RAPID DRYING WITH PULSATING CIRCULATING AIR.

53. King, W. W. Chem.Eng.Progr.9 1948 44 (9) p.716
PRECOAT ROTARY FILTER. Kieselguhr, 2 inch layer takes the filtrate. Accurately adjusted knife removes filtrate and $\frac{1}{1000}$ inch layer of K. The layer of K. lasts 12 hours to 10 days.

54. Kroell, K., Schwartzkopf, O. Chemische Fabrik v.8 n.25/26 June 30 1935 p.241-5
DAS PULSATIONSTROCKENVERFAHREN—II. Drying with pulsating circulating air; notes on drying process from standpoint of physics and thermodynamics. See also reference to first part of article by S. Kiesskalt.

55. Ladenburg, Kurt. Redniss, A. Chem.Inds. 63 (4) 598-603, Oct.1948
Tech. Enterprises Inc. N.Y.
MODERN DRYING TECHNIQUES SOLVE MANY DRYING PROBLEMS. An account of up-to-date position on the more modern processes, particularly SPRAY, VACUUM, CABINET AND TUNNEL DRYERS.

56. Ledoux, E. Chaleur & Industrie v 18 n 204 Apr.1937 p.159-64
SECHAGE PAR VENTILATION FORCEE A BASSE TEMPERATURE. Outline of system for drying by forced draft ventilation at low temperature; notes on equipment used and their principal characteristics.

57. Ledoux, E. Chem.Met.Eng.1941,48, No.10,83-5
STRATIFICATION OF GASES IN KILNS AND DRYERS. A study of the stratification of gases in kilns and driers is approached from the standpoint of a natural-draught tunnel drier, with the simplifying assumptions that the flow of hot air is frictionless and the drier is empty. The laws of heat distribution are then determined under a number of conditions.

58. Ledoux, E. Chem.Met.Eng.Jan 1942,49,92-5
STRATIFICATION OF GASES IN KILNS AND DRYERS. Shows the effects of loading and of forced draught as well as the combination of natural and forced draught.

59. Ledoux, E. Chem. and Met.Eng.53,(9) 109-10 1946
CALCULATIONS FOR SIZE OF CONTINUOUS DRYERS. Curve shewing various conditions for adiabatic operation.
Abstract by Friedman Ind. Eng. Chem. Jan. 1947.

60. Ledoux, E. Chem.Eng.p.138.Aug.1949
Attapulgus Clay Co. Phila.
CONCENTRATION BY CONVECTION. A method of low temperature concentration by the liquid percolating downwards through a packing while dry air passes upwards. A large surface is required.

61. Legault, R.R. Talbart, W.F. Food Technology.pp.34-5
Western Regional Res. Stn. Albany, Calif. Nov.1949
DEHYDRO FREEZING. Most of Quality impairment takes place in the final stage, the purpose of which is stability against microbial activity. Vol. and weight are already reduced. On the other hand, the disadvantage of freezing is the cost of transport and ice, due to bulk. Therefore combine the processes - reduce weight by drying and microbial activity by subsequent freezing.

62. Leniger, H. A. Chem.Weekblad 45 (16) 253-61 1949
SURVEY OF DRYING PROCESSES. Netherlands Symp. The mechanism of drying is discussed. A short description is given of some installations and of sublimation and infra-red processes.

63. Laughlin, H. G. Trans.Amer.Inst.Chem.Engrs.36 345-358 1940
DATA ON EVAPORATION AND DRYING IN A JACKETED KETTLE.

64. Loveless, A. H. Indus.Chem.v II n 130 Nov.1935 p.427-35
DRYING OF SOLIDS. Review of plant and theory; moisture content of solids; surface hardening and cracking; types of drier; drying sticky materials; continuous band driers; rotary driers; vertical driers; drum driers; spray driers; drier operation; air circulation; result of reheating air; vacuum operation.

65. Lurje, M. Archiv. fuer Waermewirtschaft, vol. 12, No. 1, Jan. 1931, pp. 21-23

FORSCHUNG IN DER TROCKENTECHNIK (RESEARCH IN DRYING TECHNOLOGY). Russian engineer's impressions gained on visit to Germany; German laboratories and research methods; practice at Drying Research Laboratory of Heat Engineering Institute at Moscow; training of engineers in drying technology.

66. Lurie, M. J. Fuel Econ. Conf., Wld Pwr Conf., 1947, Sect. C_2, Pap. No. 19, Prepr., 8pp.

DRYING BY MEANS OF FURNACE GASES. Drying of various materials is usually carried out by means of hot air obtained from steam and flame calorifiers; only 50-60% of the fuel heat is effectively used. Heating to 120 - 150°C. can be obtained using a steam calorifier and up to 300°C. using a flame calorifier. When drying directly by means of flue gases the fuel heat is effectively used and the heat losses depend only on the furnace efficiency. Drying by flue gases has the advantage of allowing higher temperatures to be used, thus reducing time of drying. Tests conducted at the Drying Laboratory of the Thermotechnical Research Institute of Moscow on the evaporation of water from a free surface and on drying of various humid materials at high and low drying agent temperatures showed that the rate of evaporation of moisture from the material, depends on the difference of partial steam pressures at the surface of the material and in the surrounding air or on the difference of temperatures of the drying agent and of the wet thermometer of the psychrometer. In order to use high temperatures for the drying agent it is necessary to develop special apparatus. These dryers must allow intensive mixing and rapid drying and the material must not be retained on dryers walls. The problem of the use of flue gases is closely related to a number of questions connected with the quality of the dried product. Tests were conducted in 1946 on drying coloured and glossy paper by means of flue gases obtained from a gas-fired chamber placed immediately above the paper band.

67. Lykow, A. W. Kolloid-Zeit v 71 n 1 Apr. 1935 p. 103-11

GESCHWINDIGKEITS- UND TEMPERATURKURVEN DES TROCKNUNGSVORGANGES. Velocity and temperature curves of drying process; mathematical treatment of drying curves obtained with peat, lignite, clay, and chrome leather.

68. Lyle, O. H.M.S.O. 1947. 886 pp. 15/-

THE EFFICIENT USE OF STEAM. Written for the Min. of Fuel and Power.

69. Marritius, - Schulze, H. Fenerungstechnik 19 121-7 (1931) Aug. 15

STEAM-AIR MIXTURE. Diagram for steam-air mixture; heat balance of dryer under different drying conditions; process of recooling; tables of saturation pressures for steam.

70. Marshall, W. R. Heat.Pip.Air.Condit.Sept.1945,17,472-5
PRINCIPLES OF THE DRYING OF SOLIDS. Factors influencing the drying of a variety of types of solids are discussed and applied to the problem of choosing a suitable dryer.

71. Marshall, W.R. Friedman, S.J. Chem.Eng.Handbook J.H.Perry. Mc.Graw-Hill Book Co.1950.3rd Edit Sect.13.
DRYING. Review of drying theory and equipment Design information and cost data for the common dryers is given.

72. Marshall, W.R. Hougen, O.A. Trans.Amer.Inst.Chem.Eng.1942,38, 91-121
DRYING OF SOLIDS BY THROUGH-CIRCULATION (OF AIR). Experimental studies of the characteristics of a no. of materials for through-circulation drying (i.e. where the wet solid is preformed by mechanical and/or thermal means into small lumps) are described and compared with these given by ordinary tray-drying. The first method is shown to give much the shorter drying time; essential features are a permeable bed, preforming, and the pressure drop through the bed. Characteristic curves for asbestos, $CaCO_3$, charcoal, coke, rayon, raw silk, sawdust and soap and the effect of air velocity and particle size on drying time (const.-rate period), are discussed. (From Brit. Chem. Physiol. Abst. B.I. 1943, 45). An equation is derived for the relation between the variables in the process.

73. Matson, A.F. Defour, R.E. Res.Bull.of the Incorp.Board of Fire Underwriters. Jan.1950 Nat. Fire Protection Assn.43,1950 p.260
IGNITION TEMPERATURES OF ORGANIC VAPOURS REMOVED IN DRYING. Standards and Regulations. 60.pp.

74. Merkel, F. Z.Ver.deut.Ing.67,81-4,106-8,(1923)
THERMODYNAMICS OF DRYING.

75. Meyer, K. S. Ind.Chemist.pp.5-7 Jan.1949
Results obtained with different filter aids.

76. Miller, B. F. Textile World 84,2412-3 (1934) Dec.
LOOK TO YOUR DRYER. Brief consideration of some of current drying practices and latest dryer developments, relative advantages of new and old systems in light of today's needs discussed.

77. Ministry of Fuel and Power The Efficient Use of Fuel.1944
Contains a chapter on the general principles of drying and the characteristics of the various types of equipment, with emphasis on heat consumption. H.M.S.O. 1944.

78. Moon, C. D. B. Soap.Perfumery,Cosmetics.20,(6) 573-5 June 1947

DRYING METHODS. A general article on the various methods of drying, with some illustrations of oven equipment.

79. Patterson, J. C. Chem.metall.Engng,1940,47,313.Brit.chem. physiol.Abstr.B,1940,p.577

CHOICE OF DEHYDRATION METHODS. Discusses the influence of type of application, availability of cold water supplies and relative costs of power and water on the selection of the method of dehydration to be employed in a particular case.

80. Perry, J. H. Chemical Engineers Handbook, 1950. 3rd Ed. Mc. Graw-Hill Publ.Co.Ltd.

DRYING pp.799-884 BY MARSHALL AND FRIEDMAN. The mechanism of drying of solids. Falling rate period. Case Hardening. Air Circulation and recirculation. Heat consumption. Economisers. Types of Equipment. Performance data. Calculations and psychrometric chart. Critical moisture contents, temperatures and times of drying of various materials. The Drying of gases. Tables and Diagrams.

81. Pierre, L. Chaleur et Industrie,6,327,380,425(1925)

INDUSTRIAL DRYING. Brief description of various types of dryers. Humidity relations and ventilation calculations. Rate-of-drying equation based on rate $\propto$ p.p. diff. Integrates and gets log relation. Gives data on drying malt and quotes Alliott's data on Prussian blue. Const. rate and falling rate period.

82. Rammler, and Blaschke. V.D.I.Verlag Berlin. pp.66,fig.21, 1938.

THERMAL TABLES FOR DRYERS UTILISING FURNACE GASES. The authors have attempted to present in a clear and concise form all thermal calculations required for designing and investigating dryers, especially those using furnace gases.
Reviewed in Feuerungstech. 1939, 27,62.

83. Razous, P. Dunod.Paris 259.pp.1949 5th Edit.

THEORIE ET PRATIQUE DU SECHAGE INDUSTRIEL.

84. Reavell, B. N. Inst. of Fuel: "Drying Study" March 1951

THE DRYING OF LIQUIDS, SOLUTIONS AND FREE FLOWING SLURRIES. A historical introduction and a description of the various processes and equipment types for drying the above. No data.

85. Reavell, J. A. Ind.Chemist 5 p.32.1929

FILM AND SPRAY DRYING. Brief Abstracts of papers read before the Inst. of Chem.Engrs. dealing in a general way with the subject of drying and dehydration.

86. Rue, H. E. Food Inds. 12, 18. 40-41 1940
WHEN TO STOP DRYING. Cube of material, cube container removed and the angle of side of the cube measured after slumping. Angle gauges calibrated for moisture content.

87. Ruth, B. F. Ind.Eng.Chem. 27, 708. 806-816 July 1935
STUDIES IN FILTRATION. IV. Nature of fluid flow through Filter Septa and its importance in the filtration process. Mathematical analysis, curves, illustrations; 35 refs.

88. Sambrook, K. H. Fuel and the Future 1948
USE OF OIL FUEL FOR DRYING. A discussion. Refers to the production of high grade tea in Ceylon by oil fired direct mixing dryers. This should bereassuring and should be suitable for hops etc, so long as the fuel is arsenic free. Also control of oil firing is much easier.

89. Sanderson, L. Canad.Min.J. 69 ,82-4 March 1948 92-4 May 1948
DRYING OF MATERIALS.

90. Saunders, S. G. Indust.Heating Engr. 5, 43-48 1943
ESSENTIALS OF DRYING. The properties of materials are discussed. Psychrometric charts and the drying of certain hygroscopic materials are considered individually, steam activated charcoal, wood, sea island cotton. Bibliography of recent literature.

91. Saunders, S. G. Ind.Heatg.Engr. 9, 10, 11. Nos. 36 to 47 From July 1947 to July 1949
A REVIEW OF MODERN DRYING METHODS. A series of contributions dealing with methods and equipment.

92. Saunders, S. G. Industr.Heat.Engr, Sept. 1948, vol. 10, 169-171, 177
REVIEW OF MODERN DRYING METHODS. VIII. Conduction, or contact dryers are considered, dryer surface being heated by steam, hot water, combustion gases, heated oil, electricity or gas. Particular uses and advantages are pointed out, as well as rules to be remembered for efficient and satisfactory contact drying. Two types, continuous and batch dryers are compared and the dryers belonging to each group are classified and described.

93. Schaffner, R.M. Kockler, W.A. Amer.Inst.Chem.Engrs. May 1939
DETERMINATION OF THE OPERATING COSTS OF A COMMERCIAL DRYER.

94. Schmidt, E. Zeit fuer die gesamte Kaelte-Industrie v 43 n 4 Apr. 1936 p. 75-80
UEBER TROCKNUNGSVORGAENGE. Theoretical experimental study of drying phenomena; equations and curves presented.

95. Schumacher. Gas u.Warmerfach 74,1049-52 and 1084-91 (1931).Nov.14 and 21
LAUNDRY DRYING WITH GAS. Preliminary removal of water with centrifuge and use of ironing machine least time and gas but more power.

96. Scott, A. W. Fuel and Future, Ministry Fuel Pwr, vol.1,267-277; London: H.M.S.O.,1948
DRYING OF FOODSTUFFS AND WASTE PRODUCTS. The author discusses the drying of heat-sensitive products with a high initial moisture content (over 80%) to a final moisture content of about 5%. The paper deals largely with the theoretical aspects of the various air circuits which can be used under the following headings:- Principles of evaporation into an air stream; use of psychrometric chart in dryer calculations; single stage air dryers; parallel flow drying with recirculation; counter flow drying with interstage heating; and some practical factors affecting thermal efficiency of tunnel and conveyor dryers.

97. Sharples, J. T. Inst.of Fuel."Drying Study" Jan.1951
HEATING BY ELECTRIC ELEMENTS. A description of "sheathed element" electric heaters and the advantages for direct heating and radiant heating. The wide emission range of the elements at 750°C is considered to have advantages over open wire and other elements at higher temperatures.

98. Slade, F. H. Heat.Vent.Engr,Apr.1948,vol.21,439-444
MODERN DRYING METHODS. Pt.I. The nature of moisture in a solid and the theory of drying are discussed and various drying processes including drying by mechanical separation, evaporative drying, vacuum drying and vegetable dehydration.

99. Slade, F. H. Heating and Vent. Engr.22,(260) p.388-390.Feb.1949
PROCESS HEAT IN CHEMICAL PLANT. Diagrams of Crystallisers, Supersaturation cooling and Vacuum process descriptions.

100. Smith, F. C. Elec.Rev.v 116 n 3005 June 28 1935 p.934
ELECTRIC DRYING. Article discusses importance of controlling air interchange; curves showing comparative effects of varying temperature and air velocity given; illustration of recommended type of heating unit.

101. Snijders, C. J. Jr. Chem.Weekblad 29,422-34 (1932)
DRYING IN CHEMICAL TECHNOLOGY. A review of the technological drying process, including calcns. of heat efficiency, drawings of types of app. and several examples.

102. Stewart, T. W. Jr. J.Junior Inst.of Engrs.41,105,(1930) Dec.
DRYING OF INDUSTRIAL PRODUCTS.

103. Tomlinson, M. Heat Piping and Air Conditioning 3 n 12
Dec. 1931 p.1017-20
CHARTS SHOW FUNDAMENTALS OF DRYING PROCESS. Charts presented make it possible to see at glance effect of change in one of factors which influence drying process; control instruments also discussed.

104. Tomlinson, M. Heat Piping and Air Conditioning 4 n 2
Feb. 1932 p.116-20
DRYING METHOD IS ALL-IMPORTANT. Use of proper drying method has profound effect on quality of product secured and on cost of manufacture; essential drying information charted and discussed and use which industrial air conditioning engineer can make of this information is demonstrated; characteristics of four general drying methods.

105. Travers, M. W. Inst.Fuel War Time Bull.12/1944,55-7
THERMAL DATA FOR USE IN CHEMICAL-TECHNICAL CALCULATIONS. The data are particularly for use in the compilation of thermal balance-sheets for processes involving the combustion of fuels, based upon the centigrade temperature scale, the pound avoirdupois, the centigrade heat unit, and the molar system.

106. Victor. Heat. & Vent.Engr.1944 41 (12) 67-82
CONVECTION DRYING.

107. Waddams, A. L. Internat.Chem.Engg. 31 (1) 20-23 Jan.1950
DRYING. The first of a series of Chemical Engineering subjects. It deals with developments of drying and equipment in a brief but descriptive manner. Short Bibliography.

108. Waddams, A. L. Internat.Chem.Engg. 31 (10) 452-4 1949
DRYING. Reviews rotary dryer design, pneumatic and spray drying, high vacuum and textile drying.

109. Walker, Lewis, McAdam, Gilliland McGraw Hill Book Co.1937
PRINCIPLES OF CHEMICAL ENGINEERING. P.P.612-682. A general description of drying and dryers. Fundamental principles and practical applications of theory.

110. Weisselberg, A. Thomas, C.W. Chem.Met.Eng.39,426 (1932) Aug.
Olive, T. R.
CLASSIFICATION OF DRYING.

111. Weisselberg, A. Thomas, C. W. Am.Soc.Mech.Engrs.-Trans.v 57 n 1
Olive, T. R. 1 Jan.1935 p.41-7.
CLASSIFICATION OF DRYING, INCLUDING GRAPHICAL ANALYSIS OF AIR DRYING AS DEVELOPED ABROAD. Classification of liquids as to kind, nature, and state; means available for their removal; limitations of various drying methods with regard to material being processed and results obtained.

112. Weisselberg, Arnold Chem.Met.Eng.39,426-9 (1932)
FACTORS THAT INFLUENCE DRIER PERFORMANCE. A discussion of the factors which enter into the performance of a drier, their relations to the mechanism of drying and the improvements which they suggest. The factors discussed are capacity, drying rate, evapn., diffusion (cf. C.A. 24, 1502), forced diffusion and efficiency. A Mollier water-air mixture chart is used to illustrate examples.

113. Westman, A. E. R. J.Am.Ceram.Soc.12, 162 (1929)
Mills, R. G.
WASTE HEAT DRYER CALCNS. AND CHARTS.

114. Whitaker, L. R. Brick 97 (3) 30 1940
DRYING TROUBLES. The problems of the balancing of air flow and the stream lining of flues is discussed from the practical standpoint.

115. Williams, W. P. B.P.579,898 of 24/2/1944: 20/8/1946
DRY-CLEANED GARMENTS SOLVENT REMOVAL AND AIRING APPARATUS. The claim is for apparatus for removing solvent from dry-cleaned garments with hot air with a minimum risk of fire or explosion. This is achieved by securing such a flow of air that the vapour is sufficiently diluted. Electrically operated dampers are provided to cut off the flow of hot air to the container for the wet garments if the current is reduced below the safe limit, and, in the last resort, to flood the container with steam.

116. Wilson, H. J.Am.Cer.Soc.v 20 n 4 Apr.1937 p.99-111
Skinner, K. G.
EQUATIONS AND QUADRANT CHARTS FOR DETERMINING HEAT AND AIR REQUIREMENTS OF CONTINUOUS DRIERS. Derivation of equations for heat balance from temperature, humidity, and weight data, heat and air requirements, saturation of exit vapor, and temperature required of hot entering air.

116a. Ure S.G.M. Thorpe's Dictionary of Applied Chemistry. 4.58-79.1940
DRYING AND DESICCATION. An account of the principles of mechanical and thermal drying and a fully illustrated description of the standard types of industrial drying equipment.

116b. Various Authors. Ind.Eng.Chem.13 5.1921
SYMPOSIUM ON DRYING. Six papers by Lewis, Carrier, Fleming, Merz and Ridley.

117. ---- Assocn. of Chemical Plant Manufacturers and of Food Plant Manufacturers
HANDBOOKS. 20 types of dryers with their manufacturers are indexed.

118. ---- Chem. Inds. p. 520. Oct. 1949
New Equipment announced for 1948-9. A Table of Chem. Eng. Equipt. includes about a dozen new dryers. Characteristics or description are tabulated. Short review.

119. Anon. The Steam Engineer 19(223)p.280 Apr. 1950
THE STEFCO-WILDISH STEAM DRYER, TWO STAGE. The first stage is a reversed flow separator, where the steam passes downward, precipitating moisture and impurities. The second stage is a patent baffle unit of inclined plates of non corrosive metal where the water extracted by them is forced downward to drain holes.

120. Anon. Chaleur et Industrie (Paris) v 10, p. 343-352, July 1929 and p. 397-405, August 1929. 21 figs.
CALCULATION OF DRIERS ACCOMPANIED BY J.d. DIAGRAM. (CALCUL DES SECHOIRS ACCOMPAGNE DU DIAGRAMME J-d).

121. ---- Aktiesels Kobet Denmark 25.10.43
See under Vacuum Drying.

122. ---- Br. Abstr. Bi. Cols. 25-6. Jan. 1950. U.S.P.

Air Dryer App.	C. W. Gordon	2,393, 766	1946
Dessicator Unit	J. F. Riley	2,396, 474	1946
Drying Tower	H. V. Friedman	2,394, 605	1946
Drying App.	F. M. McBeth	2,395, 933	1946
Infra. Red Oven	C. W. Attwood	2,405, 631	"
Drying Kiln Design	R. A. Simmons	2,403, 154	1945
Spray Dryer Nozzle	E. Gustafsson etc.	2,399, 182	1946
Strip Drying App.	G. S. Frum	2,402, 545	"
Vacuum Dryer	N. V. Hayes etc.	2,406, 682	"
Vertical Tray Dryer	K. Engler etc.	2,407, 636	"
Air Dryer	W. W. O'Neal	2,409, 787	"
Drying App.	C. N. Hoyler	2,403, 800	"
Dehydr. App.	T. K. Taft	2,403, 880	"
"	W. A. Patrick	2,399 504	"
"	"	2,399, 247	"
App. for Dehydr. Liquids	J. M. Hall	2,400, 458	"
Dehydr. of Liquids	J. M. Hall	2,400 459	"
App. for Freeze Drying	K. C. D. Hickman	2,402, 401	"
Dryer Construction	J. J. Mojonnier	2,387, 458	"
Appl. for Web Matl.	B. R. Andrews	2,289, 586	1945
Screw Press & Dehydr. App.	B. F. Lundy	2,386, 052	"

123. ---- Bamag-Megicin(Gt.Br.)Ltd. Feb.1928
BUTTNER UNIVERSAL DRYER. 12 pp. and figures.

124. ---- B.I.O.S.Report 452
Illustration of Drying Equipment for all industries.

125. ---- B.I.O.S.1559
ROLLER DUPLEX DRYER. See under Yeast.

126. ---- B.I.O.S.Report 1761 pt.1
Tubular Dryers in Germany.

127. Anon. (Brit.Claywkr.,52,60,1943)
MAINTENANCE AND REPAIR OF FLOORS. A drying floor is suggested in which the drying surface consists of slabs of fired clayware covered with a thin layer of concrete (1:6). The method of repairing such a floor is fully described.

128. Anon. (Brit.Claywkr,1947,55,194)
STEAM PIPES IN DRYERS. The relationship between steam pressures and the correct size of pipe is discussed. The size should be as small as possible consistent with adequate transmission of the steam, for too large a pipe leads to loss by radiation and condensation. In most dryers the steam velocity does not exceed 4,000 ft/min. A table shows the weight of steam delivered per hour at various pressures by different sizes of pipes. Cast-iron pipes are not suitable for pressures exceeding 100 lb./sq. in.; instead, steel pipes are advised. Expansion pieces should be included, and a steam trap fitted at intervals of 250 ft; it is stated that the total length of the steam pipe in a dryer shall not exceed 300 ft.

129. Anon. Chem.Age.30,358-60,Apr.28,1934
Drying ovens and Related Equipment. Description of improved Brown & Co. Ltd., drying ovens; water jacketed, hot air, vacuum, hot air sterilising types.

130. ---- Chem.Industries Buyers Guide Section
pp.764-6 Dec.1948.part 2
27 Types of dryer listed with the manufacturers of each type.

131. ---- Ind.Heat Engr.1/1949 11 45.p.12
Rosenblad Spiral Heat Exchange Equipment Description and Illustration.

132. ---- Food Inds.12.(1)81.1940
TRIPLEX DRY BLENDER. A helicoid screw apparatus for blending dried materials.

133. Anon. Genie Civil v 109 n 2827 Oct.17 1936 p.338-9

TABLES SECHEUSES DE LA SOCIETE ALSACIENNE DE CONSTRUCTIONS MECANIQUES FOUR PRODUITS GRANULEUX OU PULVERULENTS. Features of driers, for granular materials and powders, manufactured by Societe Alsacienne de Constructions mecaniques.

134/35. ---- Food Machinery Association 1950

BRITISH FOOD MACHINERY. List of members products and services. Illustr. 168 pp.

136. Alliott, E. A. J.S.C.I.38 173-85T(1919)

DRYING BY HEAT IN CONJUNCTION WITH MECH. AGITATION AND SPREADING. General Data on pan dryer. Abst. in Chem. & Met.Eng.21 620

137. Atwater, Borkland Chem.& Met.Engng.26.226 1923

Pan Dryers. Coal, Sawdust, Gypsum, Fireclay Sand.

138. Bachmann, D. V.D.I. Zeit v 79 n 34 Aug.24 1935 p.1034-8

AERODYNAMISCHE MASSNAHMEN AN UMLUFT-TROCKENSCHRAENKEN, ETC. Results of experimental study for improvement of air-flow conditions in air-ventilated driers, by application of aerodynamic principles.

139. Bartlett Snow Co. Ind.Eng.Chem.9.1948 v 40 8.100A

Cleveland 5 Ohio

ADVT. Steam jacketted batch dryer for small quantities of salts, wood flour etc.

140. Becker, R. Chem.& Met.Eng.38 94-6 Feb.1931

DRYING THE OUTPUT OF THE CHEMICAL PLANT. Description and application of various types of dryers.

141. Miller, Birney Food Inds.8 183-186 1936

DRYING FOODS. With Non-Rotary Dryers. Diagrams (white on blue) of
1. Reversing pan continuous dryer - 6 band.
2. Non-reversing pan dryer - 4 band.
3. Single band dryer.
4. Truck type batch tray dryer.
5. Cabinet Tray dryer.

142. Boulton, W. Ltd. Breeze, E. M. Brit.Pat., 570,626, 16/7/45
Beardmore, F.
IMPROVEMENTS IN DRYING STOVES. A drying stove is described in which the heat is distributed inside an inner tank within the stove. The goods descend into this tank at one end and rise out of it at the other end. Hot air is blown outwards from a central air duct extending across the lower part of the inner tank, the air rises towards the ends of the tank and is drawn back to the centre again away from the end walls by an intake, also extending across the tank, at a higher level than the inlet.

143. Brown, C. O. Ind.Eng.Chem. 41(3) A 93-4. Mar. 1949
B.I. 545. July 1949
EQUIPMENT AND DESIGN for soft materials and to avoid dust Proctor & Schwarz Dryer Mesh belt of 0.25 inch cubical metal boxes. Material pressed into the belt by rolls, heated chamber, suspended therein in draped loops several feet high, and when dry, the material is vibrated out.

144. Buttner Ind.Chemist 472-3 Nov. 1931
New Drying Systems for Chemical Products.

145. Chapman, E. M. et al. B.I.O.S. No. 812
p.3. Pamphlets, and Capacity Data on dryers for Starch, Copra Nuts Coffee etc. available on request from Buttners Urdingen.

146. Clark, L. F. Assr. to U.S.P. 2,432,964/1947
Filtrol Corp.
CONVEYOR DRYER HAVING PLURAL COMPARTMENTS AND DRYING GAS RECIRCULATION.

147. Corwin, J. F. Science 106 353 10 Oct. 1947
Hot air apparatus dryer for general laboratory use. Diagrams for glass apparatus.

148. Cruess, W. V., Clark, L. D. Calif. College of Agric. Un-numbered
Leaflet 1932
The Home Evaporator.

149. Davenport M/cy. & Foundry Chem. & Eng. News 27(16) 1164 18/4/1949
Co. Davenport Iowa.
CONTINUOUS DEWATERING PRESS. 3 sizes for Extraction of excess moisture. Illustration.

150. Dayton, H. B. Rev. of Sci. Instruments v. 19 11 Nov. 1948
SPEED OF OIL AND MERCURY DIFFUSION PUMPS FOR HYDROGEN, HELIUM DEUTERIUM. Includes a treatment of types of jet.

151. De Laval Sep. Co. BP.630,808 1.7.47
CENTRIFUGE DRYER. Hot air is induced by fan blades on to the bowl, and effects further drying of separated solids.

152. Donovan, J. Artisan Metal Products, Boston. Food Technology 1(1)1 Jan.1947
SOME ASPECTS OF FOOD PROCESSING EQUIPMENT DESIGN FROM THE STANDPOINT OF HEAT TRANSFER. Equations for Heat Transfer curves for heat transfer through various thicknesses of metals: Example calculations. LIST OF DESIGN FACTORS. 27 Items.

153. Dorfmann, H. Archiv fuer Waermewirtschaft (Berlin), vol.11,No.11,Nov.1930,pp.367-369,4 figs.
DETERMINATION OF SIZE OF FLUE-GAS DRIERS (ZUR BESTIMMUNG DER GROESSE VON FEUERGASTROCKNERN). Example is given to show that usual dimensioning of such driers does not take into sufficient consideration peculiarity of material to be dried; suggestions for proper dimensioning of drums.

154. Dwight, Lloyd Oliver Chem.Met.Eng.39,623,(1932)
HIGH CAPACITY DRYER.

155. Eidt, C. C. Food in Canada, 1943,-3 (No. 2), 14
CONSTRUCTION AND OPERATION OF DEHYDRATORS. Deals with the engineering principles involved in dehydration, with reference to dehydrator tunnels, floors, walls and doors and the mechanical equipment required in a dehydrator which is to handle 30 tons of raw potatoes every 24 hours (giving details of the primary end, the secondary or finishing end and control and recording equipment) and operation of a dehydrator.

156. Eimco Corp. Salt Lake City Chem.& Eng.News 26 46 15/11/48
Cabinet type laboratory vacuum filter test unit: is mobile. Drum or disc type.

157. Erisman, J. L. B.P.613,166;613,206.13.6.46.B.I.442. June 1949
DRYING, HEATING OR COOLING OF FLOWABLE SOLIDS. Belt with scoops from which the material cascades.

158. Erimescu, P. Eng.and Min.J1.,vol.131,No.12, June 12,1931,pp.553-554,1 fig.
INCREASING STEAM-HEAT DRYER EFFICIENCY. Outline of method of cleaning coils of steam-heated driers, adopted in connection with drying of lignite, but applicable to driers used for other purposes; it is suitable for removing oil and grease from any metallic surface, however complicated construction of such surface may be; drier performances; crust of oil products, that seriously retard heat transfer, is dissolved and removed with trichlorethylene.

159. Faber. Ind.Plastics.1946 1 8.24-5.32
Convection ovens are 26% less costly than infra-red ovens.

160. Friedman, S. J. Heating & Ventilating's Reference Section Feb.1951 pp.95 to 110
STEPS IN THE SELECTION OF DRYING EQUIPMENT. Rules are given for the proper selection of a dryer for a given service. Six examples are given to clarify the procedure in solving special problems. Emphasis is on the importance of drying as a unit operation. Methods of classifying dryers are given together with tabular representations with diagrams of over 20 types of dryer, their uses for various materials and manufacturers. Also included is a chart for enabling a selection of possible dryers to be made for the various types of material.

161. Frost, L. C. B. BP.612,835 28.2.46 B.I.333.May 1949
DOMESTIC DEHYDRATION APPARATUS. Foods are contained in a fluid-tight chamber, which incorporates a source of low temperature heat, generating infra-red rays, which evaporate moisture from the foods, the vapour passing by a lagged circuit to a condenser. Condensate is removed and dry air is recirculated. A source of U.V. light is incorporated to preserve the fructose property of fruit.

162. Gallaus, C. Tonind.Ztg. 56, 669-71, (1932)
HOT AIR DRYING PLANT. Double boiler consists of two heater systems which together with two exhausters form heating set.

163. Gilliland, E. R. Engineering 1923 115. 511. 541
THE DESIGN OF HOT AIR DRYING PLANT.

164. Glücklich, E. Tech.Bl., 1939, 29, 511. Chem.Abstr., 1940, 34, 3952
THE PLANNING OF DRYING EQUIPMENT (transl. title). Recommends (1) co-current drying for materials which can be dried rapidly and which are not hygroscopic or (after drying) susceptible to high or fluctuating temperatures and (2) counter-current drying for substances which must be dried slowly and which are hygroscopic or not susceptible to high temperatures.

165. Glücklich, E. Feuerungstech, 1942, 30, (57-62)
MODERN DRYERS. A discussion of the fundamental principles of artificial drying technique is followed by brief descriptions of modern static and dynamic dryers.

166. Grosvenor, W. M. Tr.A.I.C.E. 1 184-202, 1908
CALCULATIONS FOR DRIER DESIGN. Calculations based on the changes in air characteristics for adiabatic, steam pipe and radiation conditions. Humidity, heat transfer and radiation tables for steam pipes.

167. Greene, J. W. Chem.Ind. 61 420-1 Sept.1947
NEW EQUIPMENT. Illustrated.

168. Groskinsky, E. Ziegelwelt 62,152-153(1931).Abs.in Cer. Soc.Trans. 30,54-5,(1930)
UNIVERSAL KILN AND ITS OPERATION.

169. Anon. La Revue de Chimie.Industrielle,40, 156-8,1931
Describes driers made by the firm of Haas. Shelf and Rotary.

170. Haas, H. West.Gas.vol.7,No.9,Sept.1931, pp.34,72 and 74,1 fig.
DESIGNING A "VENTURI" DIRECT-FIRED AIR-DRYER. Notes on air-heater designed by author, embodying two features that have demonstrated their value in operation; system is flexible and can be arranged to meet variety of conditions in drying of different materials with minimum of fuel used.

171. de Haas, T. K. Chem.Weekblad. 45(20)330-3,1949
Discusses various factors governing the operation of dryers.

172. Hefner,-. and Beck,-. F.I.A.T.Microfilm Reel A-28, Frames 5261-5266; U.S.Dept.Commerce, Off.Tech.Serv.,PBL70251,27 Apr.1937, $1.50
VACUUM STEAM HEATING FOR DRYING CABINET.

173. Harcourt, G. Am.Soc.Mech.Engrs--Advance Paper mtg. Sept.17 and 18 1936 12 p.
DRUM AND CONTACT DRYING. Paper deals with cylinder, drum, agitated, vacuum shelf, and steam tube driers, etc. in which material being dried comes into actual contact with heated surfaces.

174. Häusler, W. Swiss Ass.Brick Tile Manuf.: Heat Economy in the Brick Industry,No.1,1943
INVESTIGATIONS ON THE OPERATION OF LARGE SHED DRYERS, RESULTS AND THEIR APPLICATION. A detailed report is presented of investigations carried out by the Institute of Heat Economy, Zurich, on shed dryers operating mainly on waste heat, with the aim of obtaining statistical data and formulating methods of increasing the efficiency. (16 figs., 12 tables.)

175. Henley, A. T. Trans.Inst.Chem.Engrs. 6 p.102-114.Conf. 6/12/1928
TUNNEL AND STOVE DRYING. A general account, illustrated.

176. Horgan, T. J. Proc.Chem.Eng.Group S.C.I.1935 17 65
MODERN DRYING MACHINERY.

177. Hoening, H. Chemische Fabrik v 9 n 13-14 Apr.1 1936 pp.157-60
DER LAUFBANDTROCKNER. Continuous belt driers; distinction between continuous and ordinary belt driers; examples of different types; advantages and disadvantages.

178. Hurxthal, A. O. Chem. and Met. Eng., vol. 38, No. 4 Apr. 1931, pp. 230-232, 6 figs.
SUITING DRYING MACHINERY TO CONTINUOUS PROCESSES. Requirements of driers; continuous driers; typical steps in drier conveyor-belt evolution.

179. Hutteman, E. Tonind. Ztg. 56, 18-20 (1932)
THE ERECTION COSTS OF ARTIFICIAL DRYING PLANTS.

180. Imperial Co. Imperial Chem. Age. 25, 209, (1931)
THE "IMPERIAL" COMBINED FILTER AND DRYER IS DESCRIBED.

181. Irwin, D. F. Ind. Eng. Chem. 1938 30 1002
D.L.O. Oliver United Filters Inc. Continuous Vibrating Screen dryers.

182. Jantzen, E. and Schmalfusz, H. Chemische Fabrik v 7 n 13/14 Apr. 4 1934 p. 112
TROCKNER FUER EMPFINDLICHE STOFFE. Details of drier for sensitive materials; design, operation and applications.

183. Jessiman, H. M. B.P. 617, 965, 13.11.45.
DRYING OR AIRING CABINET. The cabinet is divided into three compartments. A heating compartment (H) supplies hot air through perforated walls to the drying compartment (D) H and D are separated by a compartment having a solid base and perforated roof to prevent liquid entering H.

184. Jordan, H. Tech. Bl. (Düsseldorf), 1939, 29 204-7.
INNOVATIONS IN THE DRYING OF COAL AND SIMILAR MATERIALS. The present position in the development of dryers is reviewed in the light of German patents granted during recent years. Various types of dryers are described. From Glückauf, 1939, 75, 316.

185. Kable, G. W. Agric. Engng. St. Joseph, Mich., 1943, 24, 263
SMALL DEHYDRATORS FOR FARM HOME USE. Deals briefly with constructional features and operation of small home dehydrators and illustrates performance by typical drying curves.

186. Kershaw, F. (Proctor & Schwarz) Ind. Eng. Chem. 30 1115 Oct. 1938
DRYING MACHINERY. A general description of recent progress. Illustrations of tray and continuous dryers for cotton, porcelain objects, spun rayon, tobacco, rayon skeins, soap dryer bleached cellulose and skins..

187. Killeffer, D. H. Indus.& Eng.Chem. v 28 n 11 Nov. 1936 (adv.sec.) p.75 and 77

DRYERS. Brief discussion of recently developed types such as spray and drum driers, tray and rotary driers.

188. Kutzner, K. Chem. Fabrik 6, 155-6(1933)

DESCRIPTION OF NEW SHAFT DRYING APPARATUS.

189. Ladenburg, K. Redniss, A. Chem. Ind. 63(4) 601 Oct. '48

MODERN DRYING TECHNIQUES. In general, though cabinet dryers are relatively wasteful of heat and labour, their initial cost is small and the temperature is easily controlled. Most materials, stable in air, produced in fairly small amounts (1 ton a day or under) and sensitive to heating above 100°C are suitable for this equipment.

190. Lajeat, A. Abstr. of Paper to Association Technique de l'Industrie du Gaz en France; J.Usines Gaz, July 1946, 70, 93

INDUSTRIAL DRYING. The author has derived a formula giving weight of water evaporated at one point of a drier which agrees with practical results.

191. Lambrette, A. Pratique des Industries Mecaniques 14, 133-146(1931) July; 204-11(1931) Aug.; 247-56(1931) Sept., 293-300(1931) Oct.

LES ESSORENCES CENTRIFUGES - DESCRIPTION CONSTRUCTION, ET CALCUL, (CENTRIFUGAL DRYERS). Equipment of various makes and purpose described and illustrated; simple math. design analysis and tables.

192. Lawrence, G.N. Scott, A.W. Barnell, H.R. B.I.O.S. Rept. No. 186

DEHYDRATED POTATOES AND VEGETABLES, IN GERMANY. Process descriptions, and diagrams of Tray type dryers, Buttner Spiral Band Tray Dryer and the Imperial Dryer.

193. Lehmann, A. M. Fuel and the Future, 1948 pp. 263-266

EFFICIENCY OF CONVEYOR DRYING AND ENAMELLING PLANTS. The paper concentrates on air-circulated, direct fired conveyor, correction type ovens, heated by any fuel, but generally gas. Fuel consumption data. Radiant and Convection Heating.

194. Lincoln, E. S. New York: Duell, Sloan and Pearce, 1945, 192 pp., 13s. 6d.; rev. in J. Instn. Mech. Engrs, Sept. 1948, 142

INDUSTRIAL ELECTRIC HEATING AND ELECTRICAL FURNACES. Several aspects of electric heating are covered; room heating by convection, oven heaters, electric steam boilers, infra-red drying, melting and heat treatment furnaces.

195. Mack, D. E. Lehigh Univ. Inst. of Research — Chem. Agc, 30 Apr. 1949 60 No. 1555 p. 621

EXPERIMENTAL HEAT EXCHANGE. Short description with illustration of a 35 ft. test unit for trials with finned tubing, which is claimed to be much more efficient than plain tubing.

196. McLaren, D. M. — B.P. 513,942 (October 26th, 1939)

AN IMPROVED APPARATUS FOR DRYING CLOTHING TEXTILES, RAW FRUIT OR OTHER GOODS. Claims apparatus having heating means and a heat-exchanger unit placed in a vertical duct, which has a cool air inlet near floor level and an outlet for heated air in the ceiling. Flow of air through the chamber is caused solely by formation of the column of heated air in the duct enclosing the heat-exchanger, the arrangement devices for creating air-movement. Material to be dried is moved mechanically through the chamber on a trestle structure.

197. Mactaggart, E. F. — Institution of Chem. Engrs. Paper. 11 Jan. 1949 12 pp.

DRYING MACHINERY AND ITS DEVELOPMENT. Classification and description of various types of dryer. 22 diagrams. The selection was made from nearly 100 different types of dryer.

198. Maleady, N. R. — Indus. Heating 17 (1) 105-6. 114-5. 1950

FORCED CONVECTION OVENS IN PROCESS ENGINEERING. Features of oven design and control are discussed.

199. Mitchell, L. A. — Chem. Age v 34 n 868 Feb. 15 1936 p. 145-7

MAINTENANCE OF DRYERS. Compartment and tunnel driers, rotary driers; flat bottomed pan driers with rotating scrapers; vacuum ovens, vacuum ovens for solvent recovery; film driers and spray driers.

200. Piepenstock, H. — Chem. Fabrik 6 XIII-XIV (1931)

DRYING EQUIPMENT FOR THE CHEMICAL INDUSTRY. Illustration of shelf, band, and rotary dryers made by firm of B. Schilde.

201. Pinkl, V. — Tonindustrie-Ztg. 55, 830-1 (1931) July 16, 55, 589-90 (1930) May 18

FAULTY CONSTRUCTION OF AIR DRYING PLANTS. Anon. discussion of article in issue of May 18, 1931. Basic requirements of well-designed drying plants; faults in planning of drying installation and how to avoid them.

202. Pittsburg Lectrodryer Corp. Pittsburg — Chem.Eng.News p.191 Jan.17 1949

Advertisement. Trade mark for Dehumidifiers. Drying with Activated Alumina Range, from small lab. model of a few c. ft. per hour to the giant wind tunnel installation handling 3 tons of air per minute. Laboratory model up to 100 c. ft. per minute. Dew points as low as $-60^{0}C$ can be readily obtained. A built-in electric heating element for re-activation.

203. Porter, L. C. — Agric.Engng.St.Joseph,Mich.,1943,24,265

HOME DEHYDRATORS-HERE TODAY. GONE TO-MORROW? Notes on the development of small home dehydrators in present use.

204. Proctor & Schwarz — Chem.Eng.Progress June 1949(ref.)

PROBLEMS OF MATERIAL HANDLING IN DRYING. A classification of conveyor systems with illustrations, in 14 page pamphlet. A very informative pamphlet.

205. Rasmussen, C. O. — B.P.592,840 of 21/3/1942: 1/10/1947

CENTRIFUGAL WASHING AND DRYING MACHINE. In a washing and drying machine having a removable centrifugal drum that can rotate around a vertical shaft in a cylindrical casing and is connected with a winged wheel (A) which is driven by an air current produced by a fan or driving winged wheel in the cover of the casing, the winged wheel (A) is formed as an independent unit located in the upper part of the machine and is provided with (1) a flange for making a fluid-tight joint against the upper edge of a washing bell when it is resting on this bell during washing and (2) means by which it can be detachably connected to the centrifugal drum.

206. Reavell, B. N. — Chem.Age,Lond.,1939,40,105.Chem.Abstr., 1939,33,2270(Title only)

MAINTENANCE OF EVAPORATORS AND DRYING PLANT. Discusses maintenance requirements to ensure the efficiency of evaporators, with reference to air release valves of jacketed pans, calandrias of continuous evaporators and the operation of drying rooms or cupboards and drum driers.

207. Reavell, B. N. — Chem.Age,Lond.,1940,42,79. Chem.Abstr., 1940,34,3140(Title only)

MAINTENANCE OF EVAPORATORS AND DRIERS. Discusses the chief factors involved in maintaining efficient operation of evaporators and driers, including spray driers.

208. Redmin, A. Tech. Enterprises Ltd. — Chem.Industries p.520-1 Oct.1949

DRYING. A short review of recent progress with various dryers, notably low temperature vacuum dryers and spray dryers. Steam Tube Dryer.

209. Rendu, M. — Bull.des.Associations Francaises de Propriétaires d'Appareils á Vapeur. Bull.No.88.Oct.1949

SECHAGE DES FUMISTERIES. Massifs de Chaudières et d' Economiseurs, Gaines et Cheminées. Precautions concerning developments of faults due to faulty drying and to expansion on heating.

210. van Roll, L. Akt. Gesell fur Communal Anlagen — Swiss P.228,919 16.12.43.Chem.Abstr. 43 12 26.7.49

CONTINUOUS DRYING. Liquid or semi liquid mixtures are sprayed on the internally heated surface of rotating discs. Vapours are vented or pumped from the housing. Scrapers engage discs, feeding the solids into a screw conveyor.

211. San, M. G. de — Chimie et Industrie 64(3)310-314 Sept.1950 in French

THE APPLICATION OF A GAS GENERATOR TO DRYING EQUIPMENT. A diagram of a generator is given which burns, coke, charcoal or other cheap material. The advantages in control and safety are described. The construction appears to be very simple.

212. San, M. G. de — Bull.Agricole du Congo Belge 41(2) 464-472 June 1950 also Chem.Age.p.683. 11 Nov.1950

LES SECHOIRS ECONOMIQUES A L'AIR CHAUFFEAU GAZ DE GAZOGENE. Shews how the disadvantages of heating air for drying by the usual methods of furnace tubes or steam tubes (efficiency less than 50%) can be avoided by direct flue gas heating, with disposition of furnace flues to avoid carrying dust, to the material being dried. Diagram. Application to pyrethrum, tea, coffee and other industrial materials.

213. Seyffert. — Chem.Fabrik 4,434-5(1931)Nov.4

Another rapid dryer is described, made by Seyffert.

214. Schaffner, R. M. Coull, J. — Ind.Eng.Chem.Anal.Ed.14 590 1942

A TEMP. AND HUMIDITY CONTROLLED DRYER FOR A CHEMICAL ENGINEERING LABORATORY. Description of 5 x 5½ x 3 ft. dryer.

215. Scholz, F. — Tonind.Ztg.,66,306,1942

OPERATING EXPERIENCES WITH CHAMBER DRYERS. Developments in drying procedure have frequently ignored principles known since the early days of artificial dryers. An estimate of the heat used in a Keller dryer of the original type compares favourably with a similar estimate for a more modern installation with air introduced at the bottom and exhausted from the roof; (there is, however, some doubt as to the accuracy of these and other calculations in this paper). The air and heat requirements of modern chamber dryers, including those working on the double-circuit system, at different stages of the drying process and under different external atmospheric conditions show that very close control is necessary if the drying is to be conducted economically. Early dryers worked under a certain excess pressure and with no through passage of air. With this in mind dryers are now being run with air under pressure rather than suction and with higher exhaust temperature.

216. Scott, A. W. Fuel and the Future 1 277 1948
HEAT EXCHANGER. Example. To heat 10,000 c. ft. air per minute from 60°F. to 100°F. using exhaust air at 150°F would require an exchanger of 1,000 sq. ft. surface, and extra fan power, but one spray dryer claims to save 30% of fuel by this means.

217. Spooner, W. W. Jnl. Soc. Dyers and Colorists 1939 55 303
TEXTILE DRYING MACHINERY.

218. Spring, H. M. Paper Ind. 29 1042-5 Oct. 1947
Study of Dryer Operation to determine cause of failures.

219. Stevens, E. J. C. & I. n 35 p. 551-5 28/9/1948
Process Design:- What we can learn from the mechanical engineer in process design.

220. Stewart, T. W. Junior Instn. Engrs.-Jnl. vol. 41, part 3, Dec. 1930, pp. 105-112, 1 fig.
THE DRYING OF INDUSTRIAL PRODUCTS. Wide variety of products that are dried and types of driers.

221. Summerville, J. Brit. Pat., 567,203, 2/2/45
DRYING APPARATUS FOR CLAY, PEAT, COKE, COAL AND OTHER MATERIALS.
A drying apparatus for clay, etc., includes a hollow structure subdivided by vertically spaced grids, each having at least one lateral gas inlet port and at least one lateral gas outlet port; an upright-driven rotary shaft is disposed centrally of the structure and provided with stirrers arranged to act on material temporarily resting on the grids and passing downwards through the several compartments of the structure. The dryer has two upright gas passages disposed at opposite sides of the structure and communicating with the gas inlet ports, and with the gas outlet ports, respectively.

222. Stubbs, A. Internat. Chem. Eng. 32(2) 63-67 Feb. 1951
MODERN DRYING PLANT. I. Classification of Driers, Pre-concentration and Mechanical dewatering. The first of a series. A tabular classification of a new form is given. This article deals with evaporators, including climbing film evaporator vertical tube evaporators for crystallisation, leaf filters, rotary vacuum filters and centrifuges, and the desirability of efficient dewatering before drying.

223. Taylor, H. F. Food Industries v 8 n 12 Dec. 1936. p. 608-11 and 651-3

WHEN DRYER WOULD NOT WORK. Way in which Atlantic Coast Fisheries Co. New York, overcame drier problem.

224. Tomlinson, M. Heating, Piping, Air Conditioning 4, 482 (1932) July

Economy in Drying Aided by Vapor Proofing. Vapor-proofing of building materials.

225. Trumpelmann, E.

A SIEVELESS CENTRIFUGE. See under coal.

226. Arsdel, Van et al Ind. Eng. Chem. 11/1948 40(11) p. 2014

SYMPOSIUM ON PILOT PLANTS. Illustrations of pilot plants at Regional Research Laboratories Department of Agriculture. New Spray Dryer, Starch Dryer, Pectin and apple juice drying.

227. Wäser, B. Chem. Fabrik. 76-81 1941

PROGRESS IN HEAVY PLANT APPARATUS. XI. Drying. A review covering 1933-1939 and a bibliography.

228. Whitelock, J. H. Mech. Handl., 34, 629-636 1947

ELECTRIC VIBRATING PROCESS EQUIPMENT. Electric vibrating process conveyors are eminently suitable for drying and cooling systems, and units can be built up as desired. They are applicable to direct and indirect drying, radiant heating, and direct and indirect coolers. Vibration is automatically controlled, giving stable operation with minimum power consumption at all loads and rates of flow. The equipment can be successfully applied by the chemical, food, mining and metal, soap and plastic industries, amongst others.

229. Wilson, J. P. of Proctor & Schwarz Amer. Inst. of Chem. Engrs. 10 Nov. 1948. An address to 41st Annual meeting

MATERIAL HANDLING IN DRYING. A 14 page brochure deals with the handling of the various types of material to be dried and the methods of processing to improve the handling characteristics. 27 Illustrations.

230. Wulfinghoff Food Inds. 10(5) 290. 1938 Archiv. fur Warme wirtschaft 18 p. 336. 1937

HOW TO SELECT THE RIGHT DRYER. Type of drying process applicable to different kinds of materials.

231. ----
DRYING. Paper before TAPPI Sept. 1939. Uranine B gives brilliant color change when becoming wet as viewed in ultra-violet light.

232. Edit. Chem.Age p.186 55n 1542 29/1/1949
MEASUREMENT AND CONTROL. British Industrial Measuring and Control apparatus, Manufacturers Association.

233. Anon. Air Treatment Engr. 13(4)119-120 1950
CONTROL SCHEME FOR INDUSTRIAL GAS HEATING. Description and diagrams of application of the British Thermostat Company's control equipment.

234. Anon. J.Sci.Inst.8 p.152 May 1931
HUMIDITY CONTROL. Control instrument based on hair hygrometer.

235. ---- Symposium before British Assoc.York. Sept.6,1932.Sections A & G.
HUMIDITY CONTROL IN INDUSTRIAL PROCESSES.

236. ---- Chem.Inds.Sept.1948.63 3 p.410
New Instruments announced for process control. Some 100 instruments of all kinds are tabulated with principle features.

237. ---- Science 7/10/49
Summaries of papers read at a conference on instrumentation, the emphasis being scientific rather than practical.

238. Spurrier, H.
CONTROL. See under Paper, Foundry Cores, Ceramics.

239. Anon. Rayon Textile Monthly,1947 28 509-11 546-8.B.II June 1948
USE OF INSTRUMENTS IN MOISTURE AND CHLORINE CONTROL.

240. Bowen Engn.g.U.S.A.
SPRAY DRYER. Complete instructions for fully Automatic Control. Great Flexibility. 5-10 tons per day.

241. Binnington Geddes Canad. Jnl.of Research 10 221-3.1934
EXP. EQUIPMENT FOR ALIMENTARY PASTES. Automatic Drying. Recirculation of air. Time-humidity relations controlled by regulation of steam input, governed by action of recording pin of the wet bulb thermometer.

242. Chandler, J. B. Paper Trade J., 1948, 127, TAPPI, 482-487
TEMPERATURE MEASUREMENT AND CONTROL DEVICES. The advantages and disadvantages of (i) mechanical, or filled system thermometers, and (ii) electrical, or pyrometers and resistance thermometers are discussed. Some unusual applications in pulp and paper mills are briefly considered.

243. Cobb, J. F. U.S.Pat., 2,275,042, 3/3/42
DRYER CONTROL. The ventilator and humidifyer are operated by independent motors. The latter are controlled by a wet bulb hygrometer.

244. Coles, R. V. Electronics 22(11)82-86 Nov. 1949
AUTOMATIC CONTROL OF MOISTURE. Device for controlling moisture content of materials, particularly of continuous sheet materials.

245. Hermann, A. West Coast Lumberman, 57, 17-18, 38-9 54, (1930)
DRY KILN INSTRUMENTS AND THEIR USES. Equipment for indicating recording and controlling temperature, use of hygrometers, three classes of recording instruments; vapor-tension types. Spray controller: precautions: measurement of moisture content; drying ovens; electrical devices.

246. Huter & Diemar Deutsche Lebens Rundschau 43 p.73-5 1947 Br. Abstr. BIII June 1948
Method for continuous recording of CO_2 and H_2O vapour production. Relating to baking capacity.

247. Joesting, F. D. U.S.Pat., 2,298,827, 13/10/42
HUMIDITY CONTROLLER. Mechanism is described for the control of a flapper valve in accordance with changes in the ambient humidity.

248. Lang, M. Gesundheits-Ingenieur v 59 n 49 Dec. 5 1936 p.713-8
DIE REGELUNG HEIZTECHNISCHER LUFTAUFBEREITUNGS- UND INDUSTRIELLER TROCKENANLAGEN. Principles of automatic regulation of air conditioning and industrial drying plants, including textile driers and wood driers; dewpoint temperatures.

249. McBride, R. S. Chem.metall.Engng.1938,45,520. Brit. chem.physiol.Abstr.B,1938,p.1374.

MOISTURE CONTROL. Gives an illustrated description of a plant and controls for the Guardite process of conditioning goods (e.g. grain, tobacco, etc.) (see Vol. 11, Nos. 2089, 2175 and 2198).

250. Longworth J.Inst.Heat & V.Engrs.7/8 p.113.1945

FUEL SAVING BY AUTOMATIC CONTROLS. 8 References.

251. Oppelt, W. Engineers Digest.June 1949 X 6 184-189

FUNDAMENTALS OF AUTOMATIC CONTROL. About 60 small diagrams of electronic, magnetic and mechanical controls, with mathematical treatment, taken from

1. "Fundamentals of Automatic Control" Wolfenbutteler Verlagsanstalt G.m.b.H. Hannover, 1947 118 pp. 32 illustrations.
2. "Graphical Method for Complex Multiplication" A.E.U. Vol. 2. 1948 pp. 76-78. 4 illustrations.
3. "New methods for assessing the stability of Automatic Control Processes". Die Technik. Vol. 3 No. 7, July 1948 pp. 312-314. 7 illustrations.

252. Tustin, A. University of Birmingham. Nature No.4229.18 Nov.1950.pp.345-6

AUTOMATIC CONTROL SYSTEMS. Paper to B.A. September 1950, on schemes of control.

253. Walter, L. Industr.Heat.Engr.10 81,129,158,216. 1948

FUNDAMENTALS OF AUTOMATIC TEMPERATURE CONTROL I-IV. Main factors and methods are dealt with in detail.

254. Walter, Leo Chem.Age.61 1583 669-72.12/11/49

TEMPERATURE AND HUMIDITY CONTROL. The Uses and Problems of Automatic Regulators. Plant Control and Air Conditioning. General Treatment.

EFFICIENCY

255. ---- British Standard Test Code No. 996-1942
PERFORMANCE OF DRYING OVENS AND COMMERCIAL ACCEPTANCE TESTS OF FUEL-FIRED BAKERS OVENS.
Part 1. British Standard Industrial Test Code.
Part 2. British Standard Comprehensive Test Code for Drying Ovens.

256. Bichowsky Chem. & Met. Engng. 1940. 47 302
ECONOMISERS. Uses in drying various materials.

257. Farmer, F. R. Chemical Tr. Jnl. 113 649-651. 1943
FUEL EFFICIENCY IN DRYING PLANT.

258. Farmer, F. R. Chem. Age, 1944, 50, 5-8
FUEL ECONOMY IN THE CHEMICAL INDUSTRY. III. DRIERS: HEAT AND MECHANICAL. Discusses problems of fuel economy in the drying of the three main groups of materials; liquids; pastes, filter-press cakes, etc.; crystals and powders, and considers the choice of the best method of heating.

259. Farmer, E.H. & Six, C.G. Mfg. Chemist. 18 67-72. 1947
SPRAY AND ROLLER DRYING WITH FUEL ECONOMY.

260. Farmer, E.H. & Six, C.G. Fuel & Future 1 1948 285-287
Graphs dealing with efficiency in spray drying.

261. Franklin, C. E. L. Br. Cer. R. A. Paper 38 p. 4. Apr. 1949
EFFICIENCY OF DRYERS FOR EARTHENWARE II. CUP DRYERS. Thermal Efficiency. Methods of valuation.

(1) Efficiency of Heat Utilisation %=

$$\frac{\text{Heat actually used to evaporate moisture from ware x 100}}{\text{Total Heat Input - Heat in Condensate.}}$$

(2) Evaporation Efficiency, %=

$$\frac{\text{Heat actually used to evaporate moisture from ware x 100}}{\text{Total Heat Input.}}$$

(3) Overall Efficiency in operation, %=

$$\frac{\text{Heat required to evaporate all the moisture lost by the ware x 100}}{\text{Total Heat Input.}}$$

262. Garve, T. W. Bull. Amer. Ceram. Soc., Aug. 1948, vol. 27, 296-298.
WASTE HEAT DRYING SYSTEM. The defects of existing waste heat drying systems portaining to down-draught kilns are pointed out. It is shown that details of design and construction are vital for maximum recovery of heat and its efficient application and some newly patented features for progressive waste heat driers are presented.

263. Hall, J. F. B.P.588,467/1947
CONTROL OF STEAM HEATING, MORE ESPECIALLY IN CONNECTION WITH DRYING APPARATUS.

264. Hausler, W. Ass. Swiss Brick Tile Manuf., Heat Economy in the Brick Industry, No.3, Sept. 1946
CAPACITY, EFFICIENCY AND OPERATION OF CHAMBER DRYERS. - This comprehensive study carried out by the Institute of Heat Economy, Zürich, covers the physics of drying, with examples of various calculations, followed by a section giving the results of measurements made on actual plants. The conclusions to be drawn from these results, as regards the relation of theory to practice, are summarized, and the final section deals with methods of improving the efficiency of chamber dryers. (53 figs., 19 tables.)

265. Hutt, A. C. Fuel and Future, Ministry Fuel Pwr, vol.1, 294-295; London: H.M.S.O., 1948
DRYING, CONDITIONING AND STORING. The author discusses briefly the efficiency of drying plants, direct and indirect heating, insulation and lagging, control instruments and thermostatic control.

266. Lehmann, A. M. Fuel and Future, Ministry Fuel Pwr, vol.1, 263-266; London: H.M.S.O., 1948
EFFICIENCY OF CONVEYOR DRYING AND ENAMELLING PLANTS. The author considers air circulated, diesel fired, conveyor convection type ovens, which may be heated by any fuel, though gas predominates, to be the most efficient for general purposes and discusses their advantages over other types, and gives data comparing the efficiencies of radiant heat ovens and convection ovens as regards fuel economy and methods of operation.

267. McTaggart, E. F. Chem. Tr. Jul. p.71 21 Jan. 1949
COMPARISON OF STEAM CONSUMPTIONS.

Type	Lb. steam used per Lb. water removed
Vacuum	1.1 to 1.8
Pan	1.5 - 2.5
Film	1.2 - 2.1
Spray	1.1 - 1.7
Tunnel	2.2 - 3.1

268. Newton, Chambers Co., P.B. 595,465/1947
Watkinson, E.
REGENERATIVE HEATERS. This relates to that kind of heater in which passages formed in a regenerative mass are successively traversed by a hot gas and a colder gas, e.g., hot waste gas and air, so that heat taken up from the hot gas is given up to the cold gas.

269. Saunders, S. G. Ind. Heating, Engr. 10 (42) p. 142 July, 1948
A table of typical efficiencies of convection dryers, direct and indirect. The various factors influencing efficiency are discussed.

270. Schwalbe, F. G. Amer. Artisan, July, 1948, vol. 117, (7), 55-57
WHAT ITEMS TO FIGURE AND HOW TO ARRIVE AT ACTUAL B.T.U. FUEL COSTS. A series of examples demonstrating the way to find out, taking all related values into consideration, the exact cost of producing heat in kilns, driers and other ceramic furnaces.

271. Scott, A. W. Fuel & the Future 1. 272-3 1948
Calculations for 80% recirculation are given.

272. Stacey, A. E. Jr. Trans. A. S. Ch. E. (June 1925)
DRYING RATE EFFICIENCY.

273. Stamm, F. C. Paper Mill, vol. 54, No. 8, Feb. 21, 1931, 5 pp. between pp. 78-85, 3 figs.
DRIER CAPACITY. List of variable factors which have marked effect upon water evaporation; curve of drier temperatures showing driers in excellent condition; hypothetical curve showing effect of drier temperature on evaporation; rust and size accumulation on outside of driers; circulation within driers; curve of drier temperatures showing driers in bad condition; general observations of drier surface temperatures; theory of heat transfer. Before Tech. Assn. Pulp and Paper Industry.

274. Thor, P. Tonind. Ztg., 66, 322, 1942
ARTIFICIAL DRYING. Commenting on an earlier article ("The Tunnel Dryer," Tonind. Ztg., 66, 199, 1942, by W. Schnell; Abs. 147, 1943), the author advances the merits of chamber dryers against those of tunnels. According to figures given, the former are much more economical of space, and entail a smaller capital outlay. Maintenance costs are also less. Schnell's claim to exhaust air at 100% saturation is strongly criticised. The operation of a (patented) dryer working on the three-chamber system is described, and the amount of water removed by a given wt. of air is stated to be double that in Schnell's tunnel dryer. Discussion: In reply Schnell states that his article had not been written to advance the claims of any particular dryer. Since those processes are most satisfactory which are least dependent on the human element, a tunnel dryer, with no valves, etc., to control, is preferable to a chamber dryer. Schnell considers that the three-chamber system described by Thor is but a modification of the tunnel dryer. The calculations of space and cost and the objections to working with saturated exhaust air are contested.

275. Thor, P. Schnell, W. Tonind.Ztg., 66, 465, 1942

ARTIFICIAL DRYING. The discussion between P. Thor and W. Schnell (cf. Abs. 147, 1943, 146, 1944) on the relative merits of tunnel and chamber dryers is continued and concluded. Thor maintains his contention that the capacity per cubic metre is 50% greater in a chamber dryer than in a tunnel, insists on his figure for the cost of a tunnel dryer car park, and criticises Schnell's lack of supporting data on the degree of saturation of exhaust air and a statement that it is immaterial whether the drying air is introduced at a higher or lower temperature. Schnell contends the assumptions on which Thor's figures for capacity are based and the inclusion of extra cars as drying space. He explains that high degree of saturation of exhaust air is dependent upon 24-hr. working; it can then be obtained by common-sense methods of operation. Available heat is used to the greatest advantage in a tunnel dryer. His argument about air temperatures had been misunderstood.

276. Tonge, H. V. B.P. 579,187/1946

PREVENTING OUTWARD HEAT FLOW THROUGH OPENING OF A DOORLESS OVEN. The method of preventing outward heat flow through an opening of a doorless oven which comprises, during the operation of the oven, continuously blowing a curtain or blanket of air across the opening from perimetrical portions of the opening, such curtains being disposed in, or adjacent and substantially parallel to, the plane of the opening.

277. Vajda, O. Chem. Fabrik 25-7(1930)

HOT AIR DRYING ECONOMY.

278. Victor, V. P. Chem.Metall.Engng. July 1945, 52, No. 7, 105-109

AIR RECIRCULATION IN DRYING OF UNBOUND MOISTURE. In this study of drying by convection for removing unbound moisture from materials, the author points out that dryer performance is often limited by inadequacy of the air supply. He offers new graphical presentations of drying potential of air of various conditions and shows how economical conditions can be selected. After demonstrating the usefulness and theoretical basis of a number of "rules of thumb" used in drying calculations, he presents equations for design and for checking dryer performance.

279. Watkinson, E. Jnl. Inst. of Fuel, April, 1948

RECIRCULATION OF GASES.

CORROSION

280. Ansul Chem. Co., Technical Service Bulletin, May, 1949
Wisconsin D.S.I.R. Libr.
REFRIGERANT DRYERS. Corrosion by moist SO_2, MeCl.. Freon, Data on absorption by various drying agents:- Alumina, Silica Gel, Dryerite ($CaSO_4$), $CaCl_2$, CaO, BaO, ZnO. Illustrations of Corrosion effects.

281. Fritzsche, K. Braunkohle, 1944, 43, 58
EXPERIENCES OF CORROSION IN TURBINE DRIERS. Measurements are made of the SO_3 in flue gases for drying briquettes and a diagram is derived giving the dew-points of flue gases for different percentages of H_2SO_4. Details are given of the parts of the plant subject to corrosion, and of the counter-measures adopted (From B.C.U.R.A. Abst.)

282. Rammler, E. Braunkohle, 1944, 43, 53
GENERAL FEATURES OF CORROSION PHENOMENA IN FLUE-GAS DRIERS. A review of corrosion factors (oxygen, sulphur, ash) in briquette-drying plant, and a brief description of the effects. (From B.C.U.R.A. Abst.)

283. Simon, M. Braunkohle, 13 May, 1944, 43, 170-175
CORROSION IN LURGI DUST DRYERS. In the Lurgi apparatus, brown coal dust is mixed with hot combustion gases and subjected to the spinning action of a fan before passing to electro-depositors. The gases deriving from brown coal briquettes contain H_2S which forms sulphur oxides; consequently highly corrosive condensates collect in the cooler parts of the system. This harmful action has been the subject of study and the paper deals with measures taken for its control and prevention.

CYCLONES

284. Anon. Elect. Times, 13, Dec. 1945, 108, 768-70
MULTI-CYCLONE DUST COLLECTORS. New designs of cyclone collectors are being installed in power stations in Britain which are claimed to give results comparable with those of electrostatic precipitators. Reduction in the cyclone diameter has led to a tubular collector consisting of a large number of very small cyclones, each built up of two tubes, 6" and 4½" being the standard diameters. The efficiency is over 90% for dust from stoker fired boilers and between 80% and 90% with pulverized fuel dust depending on the size of the dust. The duplex design incorporates a secondary collector of a high efficiency type which deals with very fine dust and raises the total efficiency to 95%.

284A. Alyavdin, N. A. Legkaya Prom. 7. No. 7. 25-6. 1947
PRECISE METHOD FOR THE DESIGN OF CYCLONE SEPARATORS. A Mathematical treatment of design considerations.

285. Ateliers de Constructions L.M.S. Soc. Anon., and P.R. de Permentier
B.P. 613,660, 24.6.46. Belg. 27.4.46. B.I. 440 June 1949
CYCLONE DUST SEPARATORS. To prevent excessive loss of fines, additional partitions are fitted within the cyclone body.

286. First, M. W. & Silverman, L.
Heating & Ventilating Engr. 45(7)79-85 July 1948
FACTORS IN THE DESIGN OF CYCLONE DUST COLLECTORS. A mathematical treatment. Theoretical and empirical formulas for cyclone performance that are now available, indicate that some minor constants must be determined through experiment. They indicate the need for additional information.

287. Howden, J. & Co. Banninger, H.
B.P. 613,363, 22.6.46. B.I. 440. June 1949
CENTRIFUGAL (DUST) SEPARATORS. Longitudinal slot in the wall of a primary cyclone through which dust passes to a secondary cyclone.

288. ter Linden, A. J. Engineering, 167(165) 1949
CYCLONE DUST COLLECTORS. The author discusses some experimental investigations which aimed at the attainment of a better understanding of the flow of gas in a cyclone. The most efficient shape, and the determination of the kind of dust for which a cyclone collector might be recommended, are also considered.

289. Mode, W. F. B.P. 583,107/1946
CYCLONE SEPARATORS. This relates to separators of the kind consisting essentially of a casing having a lower conical dust-collecting part and an upper cylindrical part which surrounds a central cylindrical outlet duct arranged to discharge at its upper end through an end wall of the casing, a tangentially-directed inlet delivering the dust-laden gaseous stream into the annular space in the upper casing part at a relatively high velocity. In a separator of the above type an adjustable partition is provided to subdivide the lower dust-collecting chamber into two concentric spaces and is so disposed in relation to the outlet duct that the inner space received substantially only the inner gas layer, containing little or no dust, that travels down the outer surface of the outlet duct.

290. Murphy, J. J. Kellog Co. Chem. Inds. p. 521. Oct. 1949
DUST COLLECTORS. Filter Units of Sintered Metal. 35 microns pore size, 20-30 c.ft. min. per sq. ft. surface. Ultra sonic agglomerato Particles of less than 10 microns are agglomerated to 15 microns which is then suitable for cyclones.

291. Schneider, F. B. Gen. El. Review. 53(2) 22-29. Feb. 1950
REDUCTION OF PRESSURE DROP ACROSS CYCLONE DUST COLLECTORS.
A remarkable saving in the power required by the process can be made up to 80%. Pressure recovery accomplished by variations in the structure of the dust-separating equipment.

292. Tongeren, v. H. U.S.P. 2,378,600. 19.6.45. B.I. 440. June 1949
CENTRIFUGAL DUST SEPARATOR. A groove in the inner wall of the cyclone chamber which controls the speed, and discharge of dust particles.

293. Yancy & Geer.
CYCLONES. See under Coal.

FILM (DRUM) DRYING

294. ---- Food Inds. 10(7) 400. 1938
Welded steel drum dryer, single or double shell construction by Lukenweld Inc.

295. Bar, P. J. B.P. 541,517 (December 1st, 1941). Brit. chem. physiol. Abstr. B. I. 1942, p. 181
FILM-DRYING PROCESS AND APPARATUS. Relates to a method for drying liquid or pasty material (e.g. milk) spread in a film on an internally heated drum, which is provided with a casing extending over the greater part of the drum surface. The drum is heated internally to a temperature above 100°C. A jacket of rapidly flowing air or gas is provided round the drum, the air or gas being drawn through a comparatively small clearance space between drum surface and casing at a velocity relative to the drum of at least 10 feet per second. The amount of air used is at least 6 lbs. per lb. of water evaporated from the film.

296. Brandenburg, F. German, P. 746,685/1944, F.I.A.T. Microfilm
Reel J.I.P.B.L. 70141 O.T.S.
JACKET FOR DRYING DRUMS, REVOLVING TUBULAR FURNACES, ETC.

297. Farmer, E. H. Fuel and the Future, 1. 279-80. 1948
Six, C. G.
FACTORS AFFECTING EFFICIENCY.

298. Harcourt Chem. & Met. Engng. 45. 179. 1938
EFFECTIVE DRUM DRYING BY PRESENT DAY METHODS.

299. Harte, C. R. Jr. Indus.& Eng.Chem. v.28.n.1.Jan.1936.p.7-10
DRUM DRYERS. With special reference to equipment for chemical process industries, factors influencing selection or rejection of individual types of driers are discussed, on basis of operating characteristics and costs.

300/1. Henry, R. S. T. B.P.505,053(May 4th,1939)
IMPROVEMENTS IN OR RELATING TO ROLLER DRIERS FOR EVAPORATING LIQUID SUBSTANCES. A film evaporator comprises a trough to which the liquid e.g. milk, is admitted and a heated roller, provided with a scraper which delivers the dried product on to a moving band, which may be heated and irradiated with ultra-violet light.

302. Holmes, N. E. & B.I.O.S.No.1513
Kefford, J. F.
MNFR. OF "MILEI" EGG SUBSTITUTE. Escher-Wyss Ravensburg, 1946 roller dryer. Diagram. Mixture picked up by a large number of small discs, half in the trough, and air blast blows the liquid on to the roller dryer. Air pressure from jets =, 2-3 p.s.i. Stated to be easier to control, product more closely approaches spray dried milk in quality.

303. Jessen, H. C. Am.Soc.Mech.Engrs.Meeting.April 1950.41p.
ROLLER DRIERS AND THEIR APPLICATION TO SHEET MATERIAL AND VARIOUS PROCESS INDUSTRIES. See also "Industr. Heating" 17 Aug. Sep.1951.

304. Lewis, McAdams, Adams.
DRUM DRYERS. See under "Paper".

305. van Marle, D. J. Ind.Eng.Chem.30(9)1006-8.Sept.1938
(Buffalo Foundry)
DRUM DRYING. HEAT TRANSFER. A general description of process and apparatus for film drying of solid Products; Heat Transfer, Design Operation and Economics. No data except that under optimum conditions, over-all heat transfer on a double drum dryer is about 360 B.T.U./hour/sq.ft./^{0}F in the area between the drums and about 220 between drums and knives. Steam side coeffs.-2,650 and 450 respectively, liquid side coeffs.-1,500 and 1,800 respectively. Temperature drop through metal - 65^{0} and 35^{0}F. respectively.

306. Miller, J. H.
MODERN FORM OF ROLL DRYER. See under "Paper".

307. Oschatz, M. Chem.Ztg.57,34,(1933)Jan.14
A LABORATORY DRUM DRYER.

308. Reavell, J. A. Trans.Inst.Chem.Engrs.6p.115-126 Conf. 6/12/1928
FILM AND SPRAY DRYING. A general account with curves embodying performance data. Costs are discussed.

309. Reavell, B. M. C.T.J.128.669-671.23/3/1951
DRYING LIQUIDS AND SLURRIES.

310. Seidenschnur, F. Braunkohle,30,778-80(1931)
Producer-gas heating of flue gas drum dryer and economic principles and conditions governing this type of firing.

311. Stevens, A. H. for the Borden Coy. B.P.526,882(September 27th,1940).Brit. chem.physiol.Abstr.B,I,1941,p.7
IMPROVEMENTS IN OR RELATING TO PROCESS OF AND APPARATUS FOR DRYING LIQUID MATERIALS. Whey or other liquid containing a high proportion of sugar or other hygroscopic substance is concentrated to a solids content of at least 30% and is then applied as a continuous film to a heated roll, on which finely divided dry material is deposited to initiate crystallization. The resultant dry film is removed and ground to a powder, part of which is re-used. The liquid should be applied below and the powder above the pinch of the rolls, which run upwards.

312. Stokes, F. J. Mfg. Co. Phila. Chem.Engg.Progr.45.No.2.2/1949
NEW EQUIPMENT. Atmospheric Single and double drum dryer and flaker 160 p.s.i. max. steam pressure. Automatic Clearance to prevent damage.

ELECTRO-ENDOSMOSIS

313. —— The Engineer 8/4/49.187.4863.P.381
RAW MATERIALS OF THE HIGHLANDS. Prof. W. M. Cumming, R.T.C. Glasgow, is developing suitable electric apparatus for processing. The Hydro-Electric Board's research laboratory at Dundee has started experimental work on the dewatering of wet materials, e.g. diatomite, peat, by electrical methods.

314. O.E.A. Aspegrin Swed.P.120,713/1948.Abstr.Chim.et.Ind. 60(4)348.1948
PEAT. DEWATERING AND DEHYDRATION BY ELECTRO-OSMOSIS.

315. Casagrande, L. Reprint of the Proc. of the 2nd.Internat. Conf.on Soil Mechanics and Foundation Engg.
ELECTRO-OSMOSIS. Describes the fundamental work carried out at the Building Research Station since 1945, including the physical effects on soils etc. Biblography.

316. Casagrande, L. Building Research Techn. Paper No. 30
H.M.S.O. 1947
THE APPLICATION OF ELECTRO-OSMOSIS TO PRACTICAL PROBLEMS IN FOUNDATIONS AND EARTHWORKS. Results of tests with models and in large scale applications at Trondhem and in Germany.

317. Hinchley, J. W. Trans. Inst. Chem. Eng. 6. p. 129-30. Conf.
6/12/1928
DRYING BY PRESSURE. In discussion Dr. W. R. Ormandy quoted the drying of Peat and Ball Clay by electro-osmosis with voltages 200-600 according to the electrolyte content. Current is high. The water content was reduced very substantially 93% to 50% for Peat, and to 28% in clay in a few minutes. Mr. McNab said the process was never practical. Had been tried in U.K. Ormandy said it was practical. The work on Peat and Clay was successful in Germany, Hinchley said a voltage of 600 with water about was not practical. Current used is a function of the conductivity of the water.

318. Markwick, A. H. D. Engineering 163, 121-123, 7 Feb. 1947
Dobson, A. F.
APPLICATION OF ELECTRO-OSMOSIS TO SOIL DRAINAGE. Describes the principles, mechanism and applications of electro-osmosis, to soil drainage. Illustrations.

319. Nernst, W. Ber. Physik. Ges. III. p. 1714. 1909, 112, 1909
THE DRYING POWER OF GALVANIC ENDOSMOSIS. Theoretical considerations on the electric current process of dehydration. Example of Peat.

320. Maclean, D. J. & Civ. Eng. London, 40(2) p. 34-7. 1945. Road
Rolfe, D. W. Abstr. 12(207) 1945
SOIL DRAINAGE BY AN ELECTRICAL METHOD.
1. Account of physical investigation made at the Road Research Laboratory. D.S.I.R.
2. Large scale applications of electrical drainage tried in Germany. The work is based on using D.C. current for drawing moisture from the positive to the negative electrode. Experimental work on Harmondsworth brick earth. It was proved that the amount of water moved is in linear relationship with the amount of current, until considerable water has been expelled. The quantity is inversely proportional to the clay content. The decrease is very small at the cathode and increases to a maximum at the anode. Practical applications.

321. Overbeck, J. Th. G. Rec. Trav. Chim., 1946, 65, 556-563
and Wijga, P. W. O.
DIAPHRAGMS: ELECTRO-OSMOSIS AND STREAMING-POTENTIALS. The streaming potential E at a pressure difference P, E/P, and the volume of liquid v transported by electro-osmosis at a current i, v/i, are equal, independent of the structure of the diaphragm and independent

of its surface conductance. The value of these ratios which, in the absence of surface-conductance, equals $\varepsilon\zeta/4\pi\eta\lambda$ (where ε is the dielectric constant, ζ the zeta-potential, η the viscosity, and λ the electric conductivity of the liquid), diminishes when surface-conductance is present. This decrease can be accurately taken into account when the diaphragm consists of a single capillary of constant diameter. With real diaphragms, consisting of a network of capillaries of different shape and dimensions, the correction factor for surface-conductance cannot be computed. It has been common practice to estimate the correction factor from the ratio of the observed to the calculated electric resistance of the diaphragm. This procedure is shown to be erroneous, leading to values of the zeta-potential that are essentially too low.

322. Rutgers, A. J. Trans. Faraday Soc., 1947, 43, 102-111
de Smet. M.
ELECTROLYTE SOLUTIONS: ELECTRO-OSMOSIS, STREAMING POTENTIALS AND SURFACE CONDUCTANCE. Electro-osmotic velocity, streaming potential, and resistance have been measured for the same capillary with solutions of KCI, HCI, KOH, $CaCl_2$, and $AI(NO_3)_3$, at concentrations between 0 and 200 μ-equivalent per litre. The zeta-potentials, ζ_0 (from the classical formula of Helmholtz-Smoluchowski), ζ_{EO} (from Helmholtz-Smoluchowski's equation for electro-osmotic velocity) and ζ_E (for the streaming potential) have been calculated as a function of concentration. The ζ_{EO}/c and ζ_R/c curves coincide but deviate strongly from the ζ_0/c curves; this is attributed to the inadequacy of the classical formula (for ζ_0) in which no account is taken of the surface conductivity. An electrochemical explanation of the ζ/c curves is put forward, in connection with which a few special measurements have been carried out.

323. Wayland, R. G. U.S. Dep. Interior Bureau of Mines. Mineral Trade Notes. 25. No. 3. Spec. Suppl. 18. pp. 1947
CLAY BENEFICIATION IN GERMANY BY ELECTRO-OSMOSIS. Build. Sci. Abstr. 21 129. 1948. Br. Abstr. B.I. May 1949. 396.

FREEZE CONCENTRATION

324. Anon. Chem. Ind. 62. 759. May 1948. B. III.
Nov. 1948. p. 387

DEHYDRATION BY SQUEEZE DRYING. Mantle process. U. S. P. 2,424,663. Fruit juice is frozen. A pressure of 500-5,000 p. s. i. is applied together with controlled heat. The eutectic melts, and leaves behind about 2/3 the original volume as ice crystals. Orange juice is concentrated from 13% to 40% solids. The process is less cumbersome, slow and expensive than freeze drying; and concentration can be carried to a self preserving percentage of solids.

325. —— Food Investigation p. 13. 1948

A remark on the freeze concentration of beer, and the solubility of carbon dioxide.

326. Essery, R. E., Gane, R. J. Inst. of Brewing, 53(44 M. S.) 204. 1947
Morris, T. N.

CONCENTRATION OF BEER BY FREEZING.

327. Gane, R. Food Manuf. 23. 232. 1948

The method of Concentration by Freezing applied to Fruit Juices, Vinegars and Ciders.

328. Kiesskalt, S. Z. ver. Deutsch Ing. 90. 347-8. 1948
B. I. 533. July 1949

THERMODYNAMICS OF CONCENTRATION BY FREEZING. Concentration of heat sensitive substances e.g. fruit juices, vitamins, by freezing out water up to 400 Kg/sq. cm. pressure is increasingly used. Optimum conditions follow from phase-rule studies. The effect of pressure on the phase diagram can be calculated from the Clausius - Clapeyron equation relating pressure gradient of m.p. to heat of fusion and volume change on melting.

329. Matthews, A. G. Australian J. Sci. 1947. 10. 51-52. Chem.
Commonwealth Serum Lab. Abstr., 42. 5724. 1948
Melbourne

LABORATORY APPARATUS FOR CONCENTRATION AND FRACTIONAL THAWING.

330. Noyes, H. A. U.S.P.2,395,498,26.2.46.Appl.,26.8.40
CHILLING OF PLANT PRODUCTS. Juices for food or drug use are concentrated (after preliminary separation of solid and suspended matter) without loss of natural attributes by controlled freezing, thawing below 0°, and draining the conc. liquor (from ice crystals).

331. Noyes, H. A. B.P.617,776,17.10.44
CONCENTRATION OF FRUIT JUICE SOLUTIONS. Fruit juice is frozen to a solid block and heated slowly at less than 0°C, and a concentrated solution is run off.

332. Olive, T. R. Chem.Engr.10/1948.55(10)pp.118-9
Commonwealth Eng.,
Co., Ohio
FREEZE CONCENTRATION BECOMES PRACTICAL. Progress Report on a New Process. Eutectic Diagram for fruit sugars and water 0° to-30°C. Description of cascade concentrator, where refrigeration liquid moves counter to fruit juice flow. The latter moves downwards through troughs in cascade and crystals of ice are arrested and passed upwards to the less concentrated liquid. Heat economies. This is called the Cunningham process. Only about 1% of original sugar is removed, and yet nearly 90% of the original water is also removed. The work is done mainly with orange juice.

333. Straub, W. F., B.I.O.S.Misc.Rept.No.19.Part 1.p.230-233
Esselen, W. B.
Mangan, C. J.
FREEZE CONCENTRATION PROCESSES. The Ring-cell unit produces a frozen cylinder from which conc. juice is centrifuged. The Krause process employs a refrigerated drum which freezes the juice. The solid is chopped and the conc. juice pressed out in a worm type press at 25% conc., and then again concentrated. A discussion follows. This process is being used successfully at Haifa, for citrus juice, and can be applied to juices of vegetables.

334. Anon. Ind.Eng.Chem. 42 9.12A 16A Sept.1950
The use of infra-red heating in freeze drying is described in the waveband 2-10 microns. The use of i.r. transparent trays etc. of woven glass impregnated with teflon, polytetra-fluor-ethylene. Production should be cheapened and large scale operation might result.

335. ——— Chem.Age 16.7.1948 59, 1513.p.55
IMPROVED FREEZE DRYING. Edwards miniature unit. Freeze Vacuum Dryer L.5. Illustration.

336. ——— Chem.Inds.7/1948 63 1.34-38
General Description with Diagram. ½ column on freeze drying.

337. Anon. Chem.Age 27.5.1950 Vol.62 No.1611 p.780
IMPROVED FREEZE DRYING. The drying of A.C.T.H. hastened by use of Infra-red instead of ethylene glycol, the latter having been used at about 40° above zero. The element consists of fine wires a few inches below the A.C.T.H. vials. The time is cut to one tenth, and a much lower vacuum is used. It is not necessary for the material to be so cold, and the vials can be loosely capped. The absorption band is 2 to 8 microns.

338. Anon. Eng.News 28 9.722 27/2/1950
ABSORPTION HEATING UNIT FOR USE IN FREEZE DRYING. Proctor and Schwartz announces an infra-red unit for pharmaceuticals, foods, biologicals, surgical supplies such as sutures, blood, chemicals while in frozen state. The radiation is in certain effective wave lengths in the fundamental vibration region, allowing selective absorption and greatest % of total energy to be absorbed by the water in the product. Special trays are used transparent to radiation, or glass containers may be used.

339/40. Edit. Discovery 8(3) p.71 March 1947
FREEZE DRYING. A Brief History. Developed after attempts to dry plasma serum under vacuum. Frothing at low temp. due to release of dissolved gases. The first large scale sublimation plant was for blood-plasma in U.S.A. by Flosdorf, Stokes and Mudd using the Desivac process depending on the Stokes diffusion pump large enough to handle all the vapour at 0.1 m.m.

341. ———
FREEZE DRYING. See also under Leather and under Regenerated Cellulose.

342. Amasaki, T. Bull.Jap.Soc.Sci.Fish.9 67.1940.
Abstract in English

MOISTURE DISTRIBUTION IN A CHAMBER FOR LOW TEMPERATURE DRYING EXPERIMENTS. Investigation made of distribution of Temperature and humidity in an experimental refrigeration chamber, in which cold air is circulated by a fan. Rate of dehumidification of air in the refrigerator, as well as increase in humidity of air leaving it, were found to be proportional to the diff. in tension between the vapour present and unsaturated vapour in every part of the chamber.

343. Bradish, C.J., Brain, C.M., McFarlane, A.S. Nature 4 Jan. 1947 Vol. 159 No. 4027

VACUUM SUBLIMATION OF ICE. The five conditions for maximum rate of evaporation. Test apparatus, with Tray at $-30^{\circ}C$, product frozen to $-25^{\circ}C$ in 30 mins. and condenser at $-80^{\circ}C$. 6 cm. above Tray. Diffusion pump, backing pump, steady at 1 m.m. Rate = 1.5 m.m. recession per hour. Then temp. is raised to $25^{\circ}C$ in 2-3 hours, requiring tray temp. of $50^{\circ}C$. i.e. constant and lower rate of drying.

$$\text{Rate, max.} = 0.244 \times \frac{\alpha . P.}{\sqrt{T}}$$

α = Condensation coeff.
P = Sat V.Pr.
T = T. of ice surface.

I.C.I. has a 5 leaved tray dryer for Penicillin.

344. Bradish, C. J. Chem.Prod. 1947 10 Nos.8-9 p.60-66
Lister Inst.

FREEZE-DRYING. This is an extremely clear account of the principles of freeze drying. Refers to the app. set up at the Lister Inst. for penicillin, with diagram. Some mathematical expressions to shew the effects of interspace, and residual air pressure, but complicated arrangements of bottles etc. allow only empirical calculations for these. The cooling effect of a sublimation rate of 34 micrograms per sq.cm. per sec. = 350 watts although 1 K.W. must be supplied to the tray circulation. Ethyl Alcohol is circulated.

345. Burton, L. V. Food Inds. 1947 19 617-22.738-44

Description of Plant of Vacuum Foods Corp. of Plymouth Fla. for dried orange juice. One of the largest plants. Recently installed for 60,000 galls of juice per day. Concentration to 50% solids by vac. evaporation at 8 m.m. pressure, and then fed to a battery of 10 vertical freeze drying units arranged in pairs with 5-25 inch rotary condensers. Each unit will evaporate between 50/100 lb. of water per hour at 100-250 microns.

346. Carman, P. C. Trans. Forad Soc. 44 529-36. 1948

MOLECULAR DISTILLATION AND SUBLIMATION. Considers theoretically the evaporation rates of ice and liquids in vacuum equipment. Indicates the conditions under which surface evaporation rather than boiling takes place and relations between free path of the molecules, pressures and condenser arrangement.

347. Chambers, H. N. Inst.Chem.Engrs.Proc. 11 Jan. 1949 Adv.copy
VACUUM FREEZE DRYING. A general description of the principles, and performance of freeze drying equipment.

348. Edwards, W. & Co. J. Sci. Instr. 26 No. 4 p. 129. Apr. 1949
CENTRIFUGAL FREEZE DRYING EQUIPMENT. Illustration of small scale model as introduced by Dr. Greaves, where low speed centrifuging prevents foaming, produces thin wedges or shells with large areas. Demountable head. 2 Stages of Drying. 1. Primary drying in a centrifuge chamber. 2. Second drying and vacuum sealing in a manifold system.

349. Ede, A. J. Nature, 1947, 159, 610-611
FREEZE-DRYING CHAMBER: EFFECT OF SHAPE. A study of factors affecting the efficiency of the freeze-drying process shows that the design of the space is of material influence. The partial pressure of air near the condenser is relatively high. Any space in the system which is "screened" by the condenser also contains air at this pressure; and if this space is large, a substantial proportion of the air in the system will be driven into it when evaporation commences, so that the air pressure in the rest of the system will be considerably reduced. In this way a low value for the difference between the vapour pressures at the evaporator and condenser can be obtained even though the total amount of air in the system may be comparatively high.

350. Ede, A. J. J. S. C. I. 68 330-2 Nov. 1949
PHYSICS OF LOW TEMPERATURE VACUUM DRYING PROCESS. PART 1. A relation is established on theoretical and experimental grounds between the mean air pressure π in the desiccator, the rate of drying F, the difference between the vapour pressure α.P., at the evaporator and condenser, the distance "ℓ" between them, the diffusivity K at a pressure of 1 m.m. Hg, and the density W. of water vapour. $\alpha P/\pi = F\ell/KW$. Considerations arising from the shape and size of the desiccator, evaporator and condenser are discussed.

351. Ede, A. J. J. S. C. I. 68 12.336-340. Dec. 1949
PHYSICS OF LOW TEMPERATURE VACUUM DRYING PROCESS. PART 2. Applied to Green Peas. The effects of vapour pressure, rate of heating and thickness of layer on the temperature and ultimate quality of peas dried in vacuo on a heated tray have been studied experimentally. Higher temperatures and rates of heating than were formerly deemed advisable have given good results.
Refs. Gane. J. Agri. Sci. 38 81 1948
Pfeiffer D. C. Mech. Eng. 65 325. 1943

352. Elser, W.J., Thomas, R.A., Steffan, G.I. J.Immunology 28 433. 1935

DESICCATION OF SERA AND OTHER BIOLOGICAL PRODUCTS (INCLUDING MICRO-ORGANISMS) IN THE FROZEN STATE WITH PRESERVATION OF THE ORIGINAL PROPERTIES.

353. Flosdorf, E. W. Food Inds. 17 22-5. 92-5. 100-108. 1945
Stokes M/c Co. Phila.

DRYING BY SUBLIMATION. This presents a picture of freeze drying which is probably more informative than many others. Practically all aspects are covered. The curve shews the useful pressure differentials at various temperatures. In freeze drying, carrots and peas, e.g. do not require previous blanching, because enzymatic activity is stopped at temperatures used, and the finished product has too low a moisture content to permit deterioration in storage.

354. Flosdorf, E. W. U.S.P. 2,396,561

For hygroscopic materials, Flosdorf proposes to pack at a temperature higher than equilibrium R.H., or in air conditioned rooms.

355. Flosdorf, E. W. U.S.P. 2,400,748

Foodstuffs - to reduce costs of subl. drying - Freeze-dry chopped or diced meat in normal way, except that the frozen material is placed on shelves heated to say 100-120°C. This reduces drying time to about 5 hours instead of the 1-4 days as for biological products. Interior kept frozen and porous owing to rapid subl., but surface in contact with heat develops a non porous glazed appearance. The slight case-hardening has no serious effect on flavour or keeping qualities, which are said to be superior to that by other methods.

356. Finnegan, W. J. Ice and Refrig. 1942, 103, 45. Quick-Frozen Foods, 1942, 5 (No. 1). 16. Mod. Refrig., 1942, 45, 141

MULTI-STAGE FREEZER REVERSES HEAT-TRANSFERRING CYCLE FOR DEHYDRATING FOODS. Describes and illustrates the design and operation of multi-stage heat-exchange apparatus, arranged for the quick-freezing or dehydrating of foods. Progressive staging and control of temperature and moisture content of the air-stream in each stage, as required for the dehydration process, also form the basis of design of apparatus for multi-stage freezing of food. The only difference consists in reversing the heat-exchange and methods used for retarding evaporation in the multi-stage freezer to the rapid evaporation required during dehydration. Methods for the precipitation of moisture and de-frosting of air-cooling stages are dealt with.

357. Flosdorf, E. W. Reinhold N.Y. 1949 280 pp.
FREEZE DRYING (DRYING BY SUBLIMATION). Basic principles. Applications to Medical and Food products. Changes during the process and storage. Equipment. List of U.S. patents. Large bibliography to each section. Penicillin studies by Sherwood. Specimen mounting in acrylic resin.

358. Flosdorf, E. W. B.P. 513,466 October 13th, 1939
IMPROVEMENTS IN OR RELATING TO METHODS OF TREATING AND PRESERVING FOOD PRODUCTS AND BIOLOGICAL SUBSTANCES. A method for use in the concentration, drying and preservation of food products and biological substances (such as liquid or semi-liquid fruit juices, vegetable products, protein solutions, blood sera, bacterial cultures, viruses, etc.) consists in subliming the water contained in the substance by exposing it in a frozen condition in an enclosed chamber, without external refrigeration, to the action of a vacuum of 2.5 mm. of mercury or less and of a heat-regenerable chemical desiccant (which draws only water vapour from the substance) such as anhydrous calcium sulphate ("Drierite"). Procedures for (1) continuous bulk dehydration and (2) continuous multiple container concentration or dehydration (2-stage process) are described.

359. Flosdorf, E. W. U.S.P. 2,414,940
Suggestion for automatic control of temperature of frozen material by utilising the heat of hydration of Calcium Sulphate placed in the vicinity. The dessicant is cool and efficient.

360. Flosdorf, E. W. U.S. 2,493,062 1950
THE PROCESS OF DEHYDRATING PEAS. Peas are frozen, and mechanically separated from one another. At less than 3.5 m.m. at 20°F, 80-90% of the water is removed by sublimation. If the temperature is raised to 75°F, water is reduced to 1-2%.

361. Flosdorf, E.W., Stokes Eng. Co. Chem.Eng.Progr. 43(7) 343-8. 1947
FREEZE DRYING AS APPLIED TO PENICILLIN, BLOOD PLASMA AND ORANGE JUICE. This is a paper dealing with all general aspects of the process. A few process data, but very little fundamental data or data on the materials. At -18°C the ice recedes at 1 m.m. hour. Constant rate until ice is gone and about 95% of the water (blood plasma), which takes 80% of the drying time. To 1% M. in 90% of drying time, and to 0.5% M. takes the other 10% of the drying time. Cost too high for any but materials of high value (3d. per lb. water evaporated). The appropriate uses of oil sealed or ejector pumps are given. Treatment of optimum pressure differences.

362. Flosdorf, E.W., Mudd, S. J.Immunology. 29 389 1935
PROCEDURE AND APPARATUS FOR PRESERVATION IN "LYOPHILE" FORM OF SERUM AND OTHER BIOLOGICAL SUBSTANCES.

363. Flosdorf, E.W., Mudd, S. J.Immunol.34 469.1938
AN IMPROVED PROCEDURE FOR PRESERVATION OF SERA, MICRO-ORGANISMS AND OTHER SUBSTANCES. THE CRYOCHEM PROCESS.

364. Flosdorf, E.W., Hull, L.W., Mudd, S. J.Immunol.50 21.1945
DRYING BY SUBLIMATION.

365. Flosdorf, E. W. Modern Packaging 18(3) p.133 1945
Some packages which are suitable for high moisture products are quite unsuitable for freeze dried materials.

366. Greaves, R. I. N. Nature 22 April 1944 153 p.485-6
Drying Unit, M.R.C.
CENTRIFUGAL VACUUM DRYING. APPLN. TO BIOLOGICALS. Freeze drying prevents concentration and aggregation of molecules of protein which, when dried from the liquid state leads to denaturation of protein. Temperature is of little importance provided it is below the eutectic to maintain solid state. A slow freezing causes concentration of salts and protein, therefore freezing should be rapid. Must be a high vacuum and adequate provision for removal of vapour to attain reasonable rate of evaporation. Protein solutions froth and bubble violently, then freeze with extreme suddenness when put in vacuum. This gives an ideal product. Dissolved gases can be removed safely with a very careful reduction in pressure, but there is a liability to explosion and erratic freezing. Therefore pre freeze before putting in vacuum. Freeze rapidly to prevent concentration. Dry ice or spin freeze in a current of air at -18°C. If frothing could be controlled, vacuum snap freeze would be best (especially for very small quantities). Found 1450 revs/min. with a radius of 1 inch was more than adequate to prevent bubbles, with maximum evaporating surface. If done in the chamber, perforated discs holding a lot of ampoules which are 5° from vertical gives a wedge with adequate surface for drying. Successful for plasma. Broths and Penicillin are difficult to dry by other methods since they contain fractions which are liquid at low temperatures. Therefore keep running until 2nd component has frozen.

367. Greaves, R. I. N. Medical Research Council
Special Report No.258 1946
THE PRESERVATION OF PROTEINS BY DRYING. Contains a review of the literature on freeze drying.

368. Greaves, R. I. N. Proc. Inst. of Refrign. 43 149-164, 1946-7
Discussion 176-182

FREEZE DRYING. Provision must be made for (1) Pre freezing, preferably centrifugal spinning (2) Low water-vapour pressure at condenser, etc. As a rule of thumb, 1 watt. input will dry 1 cc. of ice in 1 hour. Conservative depth is ½ inch in 24 hours for general calculations. This is a very clear and reasoned account of the principles of freeze drying.

369. Greaves, R. I. N. 11th Internat. Congress. of Pure and Appl. Chemistry 1947. Author's summary 44-8
B. III. 433 Sept. 1948

SOME TECHNICAL ASPECTS OF FREEZE DRYING. Technique with particular reference to rapid prefreezing, production and maintenance of high vacuum, methods of regulating speed of drying and final drying and packaging of product. Importance of very dry product, and of hermetically sealing.

370. Greaves, R. I. N. Br. Science News 2. (18) 173-5 1949

SOME RECENT ADVANCES IN TECHNIQUE FOR DRYING FROM THE FROZEN STATE. 1. Preliminary Freezing, Greaves "Spin Freezing Process". Vacuum Spin Freezing at low speed to prevent frothing. Small model uses P_2O_5 and large model a refrigerated condenser. Illustrations. Primary Desiccation, expansion valves. Secondary Desiccation of "dry" material by heating. Little evidence as to whether 1% residual moisture is low enough.

371. Greaves, R. I. N. also
Campbell and Pressman

FREEZE DRYING. See under Protein.

372. Hall, J. & E., Ltd., B.P. 590,421 B.I. 5.1948
Perret, F. H.

APPARATUS FOR FREEZE DRYING. The heating of ampoules, bottles, etc. in a freeze drying apparatus is done by placing each bottle in one of the folds of a metallic strip which is arranged in sinuous folds in a framework of insulating material and through which an electric current is passed.

373. Hayes, et. al. Food Packer 1946 27 11. 24-8

PROBLEMS INVOLVED IN DRYING ORANGE JUICE BY SUBLIMATION.

374. Hickman, K. C. D. B.P. 620,573, 9,10.45. U.S., 18.10.44
Distillation Products, Inc.

VACUUM DEHYDRATION. Most of the H_2O is condensed as liquid to avoid the disadvantages of condensing large vols. of H_2O vapour as ice. Only the small quantity of H_2O vapour given off in a subsequent stage of the process is condensed as ice.

375. Hirsch, M. Refrig. Engr. 4/1946 51 4 331-4. 364-6-8
FREEZING. PHYSICAL ASPECTS, ETC.

376. Leninger, H. A. Ingenieur 61(9) pp. 3 & 4 4.3.1949
THE DRYING OF HEAT SENSITIVE MATERIALS. Reviews recent progress in freeze drying. (in Dutch).

377. Levinson, S.O., Oppenheimer, F. Samuel Deutch Serum Centre. Chicago 1948
DRYING BY SUBLIMATION. The principle of infra-red radiation for rapid desiccation of plasma and other biologicals.

378. Levinson, S.O., Oppenheimer, F. U.S.P. 2,435,503 3.2.1948. B.I. 668. Dec. 1948
DRYING OF FROZEN MATERIALS. Closed system where gas is circulated through drying chamber, a refrigerated trap to remove water and a heat exchanger.

379. Mohrhoff, W. H. Engineers' Digest 12(3) p.79. March 1951
FREEZE DRYING. A general article giving a good overall view of the process.

380. Morse, R.S., Nat. Res. Corp. Cambr. Mass. C.&I. 513-19. 1948. Gleneagles Convention. Oct. 1948
HIGH VACUUM DEHYDRATION AND DISTILLATION. A general account of freeze drying and of 5 condensation and evacuation systems, Illustrations of penicillin and freeze drying plants. Curve of the T.&Pr. relations in the vacuum drying of penicillin.

381. Morse, R. S. Ind. Eng. Chem. 39 1064-71 1947
Recent installation has rotating condenser with scraper bars, hoar frost collected in a cone and removed by hydraulic ram as a block of ice. Opinion that high vacuum equipment can be produced for any likely problem on any scale whatever.

382. Natelson, S., Weiss, M.
FREEZE DRYING. See under Coffee.

Plank, R. Angew. Chem. B. 19 36-8. 1947 B. III 187 7/1948

383. Br. & Amer. developts in high vacuum dehydration are reviewed. Energy considerations are given. German practice apparently is slightly inferior to Br. & American. Concluded that the process is probably too expensive for the food industry.

384. Powell, R. W. Proc.Brit.Ass.Refrig., 1940, 36, 61
ON THE RATE OF SUBLIMATION OF ICE. Existing data for the rate of evaporation of ice (in which the surface temperature is above the dew-point, so that no heat of condensation is communicated to the surface) are briefly reviewed and experiments carried out on a spherical surface about 9 cm. in diameter are described. Results for ice - and water-covered surfaces are found to lie close to a common curve.

385. Reithel, J. J.Chem.Educ. 24 286 June 1947
APPARATUS FOR LOW TEMPERATURE DRYING.

386. Saunders, S. G. J.Inst.Htg.Engrs. 11(45)12. 1/1949
REVIEW OF MODERN DRYING METHODS. VACUUM FREEZE DRYING.

387. Schroeder, A.L., Cotton, R.H. Ind.Eng.Chem. 40 803. 1948
DEHYDRATION OF ORANGE JUICE. Deals with Liquid Film Drying under vacuum and drying-rate data are presented and analysed. Drying rates from the liquid state are substantially greater than from the frozen state. The quality of orange juice and coffee is not significantly impaired.

388. Schroeder, A.L., Schwarz, H.W., Chem.Eng.Progress. 45. 6. 370-6.
Nat. Res. Corp. Cambridge, Mass. 1949
LOW TEMPERATURE VACUUM DEHYDRATION. A general review of high vacuum dehydration is presented. Equipment and operating costs are discussed to illustrate progress made in the last ten years. Two general types of vacuum dehydration are discussed, sublimation drying and liquid film drying.
Illustrations of plant.
Diagrams of 5 types of High Vacuum Drying Systems.
Pressure/Time curves.
Vertical bulk type (scraper) Continuous Vacuum Dryer.
Coffee extract dryer.
Curves repr. pumping costs. 14 refs.

389. Schwartz, H. W. Ind.Eng.Chem. p. 2028-2033 40 11. Nov. 1948
The thickness of the puffed film has no effect on the water release.
See under Coffee and under Orange Juice.

390. Schwarz, H.W., Penn, F.E. Ind.Eng.Chem. 40 938-44. 1948
PILOT PLANT DESCRIBED. See under Orange Juice.

391. Shackell, L. F. Amer.Jnl.of Physology 24 325. 1909
Suggests freeze drying for biologicals.

392. Stokes, F. J. M/c Co.
Model 2004-L has a freeze drying area of 12 sq. ft. and uses one compressor for both pre-freezing and condensation. Freon refrigeration. Drying capacity of 5 litres per day.

393. Tschudin, K. Helv.Phys.Acta. 19 91-102 1946
Evaporation of ice in vacuo at temperatures $-85^{0}C$ to $-60^{0}C$. Drying rate about 94% of possible maximum rate as calc. from Kinetic theory.

393a. Uber, F. M.,
General Editor
Interscience Publishers Ltd.,
2a Southampton Row W.C.1.
680pp. 146 Ill. 26 Tables
BIOPHYSICAL RESEARCH METHODS. Includes "Quick freezing and Freeze Drying Process by E. W. Flosdorf.

394. Wilke, C. R. Chem.Ind. 63 34-8.122-4.1948
General review of freeze drying .

HEAT PUMP

395. —— Esherwyss Pamphlet
Drying of Sausages by Heat Pump action at suitable low temperature for maintaining good taste and appearance.

396. Evans, J. H. Jnl.Inst.Heat and Vent.Engrs. 16(47) 217-251 Aug.48
HEAT PUMP PRINCIPLES AND APPLICATIONS. Paper and Discussion.

397. Fox, R. J. Ind.Eng.Chem. 7 1065.1915
THE REVERSED HEAT ENGINE AS A DRYING MACHINE. Theoretical discussion of a proposed heat cycle to be used for positive air circulation drying system.

398. Joder, F. J.Inst.Marine Engrs, 1948,60,223-235;
B.C.U.R.A. mon.Bull., 1949,13,58
HEAT PUMP WITH NOTES ON ITS APPLICATIONS TO AIR-CONDITIONING IN LAND AND MARINE SERVICE. Various types of heat pumps are described and their applications indicated. Means are outlined for utilising existing refrigerating installations with additional compression stages which also can serve as heat pumps. The air-cycle heat pump is of special interest for ventilating and air-conditioning; the Laure' pressure exchanger may supplant the auxiliary vapour-compression machine in the air-conditioning field. Comparative costs for various types of heat-pump installations are given.

399. Meier, C. A. Modern Power & Engg.39(2)41-43.1945
HEAT PUMPS. APPLICATION. Use of Ethyl Bromide is discussed. The heat pump can be used to advantage with dryers and evaporators (waste heat from) and the latter brought back to the process. Applications to a rayon plant, to evaporation of milk and in paper manufacture have been made.

400. Mitchell, T.
HEAT PUMP. See under Fruit Juices

401. Nederland, Bronswerken, Fabrick von, Dutch Patent 65,123
Diepenbrock, E. W. van 16/1/1950
DRYING OF SOLID SUBSTANCES. Use of heat pump for heat recovery.

402. Peter, R. Chimia.Switz.3 114-18.1949
HEAT PUMP FOR HEAT EXCHANGE AND EVAPORATION IN THE CHEMICAL INDUSTRY. A review of principles. In practice it is possible to obtain more than 4,000 K.cals. per K.w.hr. for heating, and more than 20,000 Kg. cals. for evaporation. As a rule of thumb, a heat pump becomes economical when cost of 1 K.w.hr. of electricity is not more than ½ K.g. of good coal (for heating) and not more than 1 K.g. of good coal for an evaporation process. Use in viscose factory, for concentration of lye, glycerol, etc.

403. Smith, H. L., Jr. Pulp Paper Mag.Canada.50 9.84-6 1949
Chem.Absts.8677 43 21 10/11/49
THERMAL COMPRESSION EVAPORATION OF SULPHITE LIQUOR.

403a. Spoern, P., Ambrose, E.R., J.Wiley & Sons N.Y.
Baumeister, T. Chapman & Hall, London.
HEAT PUMPS. Discusses space heating as well as the evaporation of liquids and the drying of solids. 188 pp. 111 figs. and illusr.

404. Sulzer Bros. Ltd., Winterthur — Sulzer Techn. Review No. 1 p. 37 1948

LOW TEMPERATURE DRYER 40°C. The moisture in the outlet air from the dryer is condensed in the evaporator of an Ammonia Heat Pump, the dry air is passed to the condenser of the Heat Pump, warmed to 40°C and passed again to the dryer. Thus the water from the material is passed out as water and not as vapour.

405. Thomas, T. F. — J. Inst. Mech. Eng. 1948, 151, 30-39

AIR CYCLE HEAT PUMP: APPLICATIONS FOR COMBINED HEATING AND VENTILATING. The pump is based on an open-circuit "air cycle". An expansion engine, compressor and fan make up the basic plant. The base circuit and several variations are shown schematically. The efficiency of the pump is discussed for its various uses under the headings of performance ratio, fresh-air heating ratio and air-drying ratio. Diagrams illustrate the performance of pumps; for a reversible cycle a close approximation to Carnot's cycle is reached. Some applications of the "air cycle" are described and the function of the components in each of these is examined. Good performances of the few existing pumps are reported. There are a number of entropy charts and tables of data. A discussion follows the paper.

406. Wall, T. F. — Discovery, p. 264, Sept. 1944

THE HEAT PUMP. The use of the heat pump and its applications are described. It is stated that the installation of such a pump is justifiable only when there is a sufficient quantity of water available at a low temperature level and when cheap electrical power is also available. The temperature which it is desired to attain must not be greater than 70°-80°C.

HIGH FREQUENCY. RADIO FREQUENCY.
DIELECTRIC HEATING

General Principles

407. ---- Sci.Libr.Bibl.Series No.614.1944
SOME REFERENCES ON HIGH FREQUENCY HEATING. 29 Refs.

408. ----- North West Tech.Inst.Library Evanston, Ill.97 pp.Aug. 1946
BIBLIOGRAPHY ON HIGH FREQUENCY AND INDUCTION HEATING. Classified and arranged alphabetically according to author, in each section.

409. Anon. Textile World 95(11) 151-153.1945
DIELECTRIC HEATING APPLIANCES: EFFICIENCY. Costs of H.F. heating. Dielectric properties of some textile materials are tabulated, and a formula for calculating the heating effect is given. Dimensions are given. It is shewn how maximum frequency can be calculated. Loss factor and design of electrodes are discussed.

410. B.I. Callenders Co. 1. Br.Pat.607,572.8/2/1946
Static Condenser Co. 2. Br.Pat.607,170/339 28/30/1/46
B.T.H.Co. 3. Br.Pat. 608,247 9.12 1944
1. Apparatus for heating materials by H.F. electric currents.
2. Radio Frequency heating apparatus.
3. H.F. Heating Apparatus.

411. Connel, L. J. C. G.E.C.Jnl.1944.13 10-32
RADIANT AND INDUCTIVE HEATING APPLIANCES.

412. Connell, L.J.C., Humphreys, A.W. and Rycroft, J.L. Paper to Inst.Elect.Engrs; Chem.Tr.J.13 Apr.1945,116, 393-395).
THE PLACE OF RADIANT, DIELECTRIC AND EDDY-CURRENT HEATING IN THE PROCESS HEATING FIELD. In process heating the main developments have been the use of electric lamps as a source of radiation and the application of high frequency heating particularly to dielectrics. The design and materials of filaments and reflectors are discussed, and the use of resistor exposed elements reviewed. Dielectrical high frequency heating, as used in paint and lacquer drying and in the plastics industry is discussed, as well as eddy-current heating for electrically conducting materials. High heat inputs can be obtained with very small temperature gradients in the material, affording even heating and shorter drying time.

413. Debruyn, H. P. Bull.Soc.Belge Elect.,Jan.-Mar.1948, 64,1-18.
HIGH FREQUENCY HEATING. A general account is given of the theory of h.f. induction and dielectric heating. Industrial applications touched upon include welding and surface heating of metals, wood drying and thermal treatment of plastics.

414. Duryee, L. M. Elect.Engng.1948,67,747; J.Iron Steel Inst.,1949,161,64.
ECONOMIC ASPECTS OF RADIO-FREQUENCY HEATING. A table of the proposed band-no designations for the frequency bands used in high-frequency heating is given with cost data based on American experience in the use of the process. One example compares the costs of flame-tempering and induction-tempering of axe heads; another compares the times for baking cores in ovens with drying by dielectric heating.

414a. Friedman, S. J. Inst.Eng.Chem.Jan.1946 p.22.
OPINION. Method costs from 0.2-2.0 cents a pound of water removed and therefore appears attractive only for the drying of expensive material, foods, etc., where quality is of first importance. Still an art, as no data have been published which will permit estimation of drying cycles or equipment sizes from the characteristics of the material to be dried and the operating variables.

415. Hartshorn, L. and Rushton, E. Bull.L'Pool Engng.Soc.,1945,18,(5),11.
EXPERIMENTS ON HIGH-FREQUENCY HEATING. A brief account is given of three new electrical methods of process heating: dielectric heating for non-conducting materials; eddy-current heating for metals and other good conductors; and radiant heating, mainly for surfaces of all kinds. The success of all these methods depends on the fact that the transfer of energy is governed by electrical properties rather than thermal ones. In all these methods the distribution of heat in the heated body depends on the absorbing properties of the material, and these must be studied in any application of the processes. Special difficulties arise in dielectric heating on account of the very wide variation in such properties shown by many common materials. Small scale experiments are described on the application of high-frequency heating to three processes: the drying of vegetables in the form of compressed blocks, the sterilisation of meat preparatory to canning, and the gluing of structures of laminated wood. The properties of the various materials were measured and are considered in relation to the observed heating effects.

416. Hartshorn, L. Nat... 157, 607, 1946.
RADIO-FREQUENCY HEATING. Radio-frequency heating depends on the production of concentrations of power in the form of electromagnetic vibrations in the coils and condensers of oscillatory circuits. The generators used are in principle the same as those used for wireless transmission; their mode of operation is outlined. The transference of power to the body which is to be heated depends, if the body is a non-conductor, on its permeation by magnetic and electric fields; the heating in this case is due to the electric stress set up within the material, and is known as dielectric heating. In the case of metals, on the other hand, heating is due to induction. Dielectric heating is usually carried out at as high a frequency as possible; if the material is homogeneous and the field uniform, the heat is uniformly distributed throughout the whole of the material.

417. Hartshorn, L. Proc. Roy. Inst. of Gr. Br. 33 541-553 1948.
RADIO FREQUENCY HEATING. A lecture dealing with the principles of high frequency heating of metals and dielectrics.

418. Jelinek, R.V. Linford, H.B. , Industr. Engng. Chem., 41. 962, 1949
McMahon, E.K. and Schutz, P.W.
DIELECTRIC HEATING OF GRANULAR MATERIALS. The relationship between heating rate and particle diameter has been investigated in the dielectric heating of crushed fused silica over the particle size range 0.295-2.54 mm. Different sizes of the material were placed in the three compartments of a rectangular polystyrene cell and subjected to approximately 1,250 V/cm. at 16.5 Mc/s. From observed temperature rises, heating rates were calculated and expressed as ratios of the heating rate of an arbitrarily chosen standard size (0.542 mm.). A maximum heating rate was found at 1.41 mm.; this rate was 3.17 times that of the standard size. A minimum heating rate was indicated in the vicinity of 0.42 mm. At a voltage gradient of 1,350 V/cm., the 1.41-mm. particles were found to heat at the rate of 2.5°C/min. These results are compared with those of earlier work with alumina and silica. The phenomenon of change of heating rate with particle size is discussed. (4 figs., 4 tables.)

419. A. E. L. Jervis, Electrician 29/12/1944, 133, 577-80;
E.R.A. Abst.
H.F. DIELECTRIC HEATING. After indicating some of the applications of this method of heating the author gives an account of the theory.

420. Jolly Trans. Amer. Soc. Mech. Engrs. 69. 155-62-1947
HIGH FREQUENCY HEATING OF NON-CONDUCTING MATERIALS. General theory and uses of H.F. heating are reviewed. Rapid and uniform thawing of frozen materials is possible.

421. Jouguet, H. Mém. Soc. Ing. Civ. France, May-June 1947, 100
283-308
HIGH FREQUENCY HEATING. A theoretical account is given of the problems of H.F. induction heating. A study is made of the influence of specimen shape, and a number of form factors are introduced. Principles governing furnace design are touched upon.

422. Kinn, T. P., Food Inds. 21(2)74-5. Feb. 1949
Westinghouse Corp. Baltimore.
THESE CHARTS ANALYSE DIELECTRIC HEATING. These charts give speedy cost evaluation of applications such as defrosting, dehydration, de-infestation and mold inhibition. Illustrations.

423. Knox, J. B. Elect. News Engng. 1 May 1945, 54, 52-5
FREQUENCY LIMITATIONS IN H.F. HEATING. Both induction and dielectric heating are considered, and a frequency spectrum is given showing the various applications of these techniques and the coverage of the types of generators available. Limitations are considered on the basis of process requirements and efficacy of generation.

424. Langton, L. L. Wireless Wld. 1 1945, 51, 17-18; E.R.A. Abst.
FURTHER NOTES ON A SMALL DIELECTRIC HEATER. Further to the description of a small dielectric heating equipment, which was published in the Sept. 1944 issue of the journal, the author discusses some of the reasons which influenced the choice of circuit arrangement and other points which arise in the design of R.F. equipment.

425. Maddock, A. J. Electronic Engng. 17 635-639 1945
HIGH FREQUENCY DIELECTRIC HEATING CALCULATIONS. The author develops the series of calculations involved in designing a system of high frequency heating and provides graphs of (1) Energy/Temperature rise, (2) energy/power for various time intervals, (3) Power/voltage gradient at 10 Mc/sec, and (4) voltage gradients for other frequencies. These graphs occupy the four quadrants of a set of axes and make up two pages of "heating charts", are in metric and centigrade units, and the other in inches and degrees Fahrenheit.

426. Maddock, A. J. J. Sci. Instr., 23, 165, 1946
DIELECTRIC HEATING. Dielectric heating is the method of heating non-metallic materials by the passage of a high-frequency current through the material, the latter in fact forming the dielectric of a condenser. The method is characterised by the fact that the material is heated quickly and uniformly throughout. The theory of the process, energy and power relations, the choice of frequency for a given material under given conditions, and the practical applications of the method are discussed in this paper. It has been applied to the drying of various materials, such as textiles, paper and ceramics

427. Madson, C. J. Ceram. Age, 45, 232, 1945

PRINCIPAL LIMITATIONS OF DIELECTRIC HEATING. The advantages of high-frequency energy are enumerated, but it is pointed out that dielectric heating is applicable only to materials normally considered poor conductors of electricity or insulators; the thickness of the material must be reasonably uniform if even heating is desired. The use of frequencies above 20 megacycles is considered undesirable when powers above about 20 kv. are involved. Limiting figures are given for the voltage gradient. Materials which have loss factors below 0.0005 are exceedingly difficult to heat by dielectric methods. Heat is not generated in the electrodes to any appreciable degree by the dielectric heating process, but the electrodes may be heated by heat transfer from the dielectric material being processed, and this may become a limiting factor in some processes.

428. Mann, C. India Rubber Wld, 1948, 118 68-71

APPLICATION OF HIGH-FREQUENCY DIELECTRIC HEATING TO RUBBER AND PLASTICS. Details of equipment, advantages and maintenance are briefly reviewed together with present and possible applications in the rubber industry.

429. Mann, C.H., Ceaglske, N.H., Olson, A.C. Ind. Engng. Chem. Aug. 1949. 41(8) 1686-169
1694

MECHANISM OF DI-ELECTRIC DRYING. The influence of variables on the rate of drying of sands was investigated. The mechanisms of drying were similar to that for other methods but the rate higher. The rate was lowered by increasing the velocity of air at a lower temperature than the sand.

430. Norris, E. T. Elect. Rev. 1944, 135, 472-4; Jnl. Textile Inst. 1945, 36, A. 80

RADIO-FREQUENCY HEATING: APPLICATION. The author weighs up the advantages and disadvantages (prime and running costs) of radio-frequency heating and concludes that the following characteristics appear worthy of consideration: (1) For dielectric heating, the generation of heat homogeneously within the material, resulting in uniform distribution of temperature in materials of poor thermal conductivity; (2) for induction heating, the generation of heat superficially in the material, resulting in uniform distribution of temperature over the surface, a useful achievement in the surface treatment of metals and in the curing of plastics; and for either type of heating, (3) the accurate localisation of heating for a particular treatment; (4) a higher rate of heating, and therefore increased production; and (5) ease and accuracy of control of the degree of heating.

431. Nyrop, J. E. B.P.620,845,3.6.46.Denm.26.6.42
METHOD OF DRYING, CONCENTRATING, OR DISTILLING HEAT-SENSITIVE SUBSTANCES. The substance is heated, in vacuo, by a high-frequency electric field. The electrodes are perforated to enable vapour to pass through them and care is taken to avoid voltages great enough to cause discharge.

432. Patelhold Patent Verwertungs und Electric Holdings A.G. Ind.Chemist.p.766.Nov.1948 B.P. 606,165
VAPORISING LIQUIDS BY H.F. INDUCTION. The liquid is sprayed at top of an inverted perforated cone. Cone itself and a centre vertical rod are the electrodes, one of which can be subdivided for graded potential. Vacuum removal of moisture through the cone. Chamber outside the cone is cooled by pipes.

433. Rector, B.E. Brit. Plastics, Feb.1947,19,56-60
RADIO-FREQUENCY HEATING. Radio-frequency heating implies the use of alternating currents from 200 kilocycles to several hundred megacycles per sec. There are two methods of application, by induction for a conductor and dielectrically for a non-conductor. The first method has the advantage that as frequency increases, the induced current tends to concentrate near the surface of the conductor, giving a "skin effect". This means that e.g. depth of hardening of steel may be accurately controlled. Applications of both methods are briefly reviewed, including hardening, brazing, curing of plastics, etc.

434. Rediffusion Ltd. Electr.Review.137 437-438 1945
HIGH FREQUENCY HEATING EQUIPMENT. Equipment with air cooled electrodes for baled wool or refractory bricks, a continuous conveyor dryer for thick fabrics or paper, with subsidiary air heaters.

435. Ribaud G. J.Phys.Radium 1947 VIII 8.97-101 BIII 438.Sept.1948
THE HEATING OF DIELECTRIC SUBSTANCES BY HIGH FREQUENCY.

436. Rinn, T. P. Food Technology 1 No.2 161-173 Apr.1947
BASIC THEORY AND LIMITATIONS OF HIGH FREQUENCY HEATING EQUIPMENT. Diagrammatic and Tabular representations of induction and dielectric heating. Power needed varies as Mass x Sp.Ht. x (t_2-t_1). Depth of Penetration varies as $\sqrt{\frac{\text{Resistivity}}{\text{Frequency}}}$. For efficient heating, the depth should be less than one third the thickness. For Dielectric heating:- Power density varies as Frequency x Voltage^2 x Loss Factor.

Frequency = Speed of Displacement of particles.
Voltage = Degree " " " "
Loss Factor = Friction Coefficient of particles.
Diameter of condenser plates should be not less than $\frac{1}{16}$ of wave-length.
Close plates = High capacity and low frequency.
Thick specimen = High frequency.

437. Robiette, A. G. Iron Coal Tr.Rev, 6/10/1944, 491-6

HIGH FREQUENCY HEATING. Some aspects of the application of high-frequency heating are reviewed and its immense possibilities are indicated. Regarding the heating equipment available, the author confines the discussion to those features which affect the choice of equipment for a particular application and illustrates the economics of the system by a simple, concrete example. High-frequency heating can produce certain metallurgical results unattainable by any other process.

438. Rusca, R.A. Amer. Inst. of Engrs. Aug. 1947

BIBLIOGRAPHY OF H.F. DIELECTRIC HEATING. Not complete but one of the most comprehensive published thus far. Lit. and patent citations classified as Domestic and Foreign and arranged alphabetically by title in these two categories: Author index.

439. Simmons, A. L. Institution of Production Engineers:
Australasian Engr, Feb. 1945 44, 35-44

HIGH FREQUENCY HEATING IN PRODUCTION ENGINEERING. The theory of dielectric and induction heating is explained with examples of their applications, and the methods of producing the necessary high-frequency current are described.

440. Slade, F. H. Heat and Vent. Engr. 22 (255) 108-115
Sept. 1949

PROCESS HEATING BY [illegible] MEANS. A good elementary description of induction and dielectric heating and its applications to both metals and non-metals [illegible] precooking for subsequent freezing; also to timber.

441. Stevens, R. L. Inst. of Chem. Engrs. Paper. 11 Jan. 1949
3 pages

RADIO FREQUENCY DRYING. A description with 6 diagrams of the mechanism of dielectric heating and drying. The method of calculating cost is given, and a figure of 0.63d. per pound of water evaporated is quoted.

Applications

442. HIGH FREQUENCY.

See under:-

Foundry Cores	under	Calhoun
" "	"	Crannel
Food	"	Swenson
Grass	"	-
Leather	"	Smith P.I.
Vegetables	"	Sherman
"	"	Dunlap
Timber	"	Jervis
Timber		F.I.A.T. 409.866
Wool		Cassie

443. ---- Automobile Engr.1946 V.36,p.438 Oct.
CORE BAKING: U.S. Developments in the use of dielectric heating. See under "Foundry Cores".

444. Anon. Elect.Wld,28/10/1944,122,91-93; E.R.A. Abst.
HIGH-FREQUENCY HEATING OF NON-METALLIC MATERIALS. Thermex dielectric heating units of the Girdler Corp., Louisville, Ky are described. Applications with wood, plastics, textiles, rubber etc. are discussed.

445. Baker and Franklin British Ceramic R.A. Research Paper 75 1950.
DRYING EARTHENWARE PLATES BY RADIO-FREQUENCY HEATING. See under "Ceramics".

446. Baumgartner, H. Brown Boveri Rev., 33,204,1946
HIGH-FREQUENCY HEATING IN INDUSTRY. Research and application are discussed with reference to vulcanising rubber mixtures, drying wood, and case-hardening by the static and feed processes. A fourth section deals with high-frequency generators for industry.

447. Baumgartner, H. Elektrizitätsverwertung, Feb.-March 1947, 21, 221-233 E.R.A. Abs.
INDUSTRIAL APPLICATIONS OF H.F. HEATING IN VARIOUS MANUFACTURING PROCESSES. Examples of industrial applications of h.f. heating include moulding of plastics, wood-glueing, vulcanising, various drying processes, brazing and steel hardening. Appropriate frequencies and powers are given, together with photographic illustrations of h.f. generators for powers of 1 to 15 kW.

447a. Brown, G.H., Hoyler, C.N. and Bierwirth, R.A. New York: D.Van.Nostrand,1947,370pp. E.R.A. Abstr.
THEORY AND APPLICATION OF RADIO-FREQUENCY HEATING. This book was prepared as an aid to industrial engineers who may have occasion to use high-frequency meeting. The latter half of the book is concerned with applications, including: annealing brass and bronze; paint baking; brazing; case hardening; wood gluing; dehydration; pasteurization; sterilization; cooking; etc.

448. Descarsin, M. Onde Elect.,No.241,121,1947
INDUSTRIAL APPLICATIONS OF HIGH FREQUENCY. The various ways in which high-frequency methods of heating are or could be applied in industry are reviewed at length, and the theory of, and equipment used in heating by dielectric loss and by induction are described. (29 figs., 3 tables.)

.449. Hartshorn, J. J.Roy.Soc.Arts, 22 Dec. 1944, 93, 38-49; B.C.U.R.A.Bull.

HIGH FREQUENCY HEATING. Dielectric heating of non-metals by means of a high-frequency electric current has been widely used in the manufacture of laminated materials for the aircraft industry. In this process a stack of many layers of wood, paper or fabric, interleaved with thin layers of a synthetic resin, is brought under pressure and then heated throughout until the resin flows into all the interstices in the material. By means of high-frequency electric heating the process has been greatly accelerated. The same method has been applied with success in the plastic-moulding industry, in the drying of tobacco and artificial sponges, to replace drying in ovens and kilns, and also in medical practice as a means of providing localised heating.

450. Leason, D. B. Refract.J., 22, 13, 1946

RADIO HIGH-FREQUENCY HEATING. High-frequency heating is stated to be well-suited to the drying of materials which have no low critical temperature, but which have a poor thermal conductivity. It is therefore considered applicable to the drying of clayware.

451. Netushil, A. V. Vestnik Inzh. & Technikor p. 141-148 - 4/4/1947 Engineers Digest Oct. 1948 9 (10) p. 343-6

DRYING OF WOOD WITH AID OF H.F. CURRENTS. Mathematical and Electrical Treatment. 11 Diagrams. see under TIMBER.

452. Neutushil, A. V. and Goldblatt, B. A. Elektrichestvo, Apr. 1948, (4), 12-17

H. F. DRYING OF TIMBER. Advantages of H.F. drying of timber are investigated. Experimental curves and formulae are introduced for calculating losses in the timber, taking into account structural anisotropy. A 50 kW. generator is described as used in timber drying. See under TIMBER.

453. Nonken, G. C. Paper Tr.Jnl. 118 1944 T.A.P.P.I. 59-61

ELECTRONIC HEATING DEVICES. INDUSTRIAL APPLICATIONS. Frequencies up to 30,000,000 are used. Fundamental equations are used to predict size and type of equipment needed and various theor. and pract. considerations are discussed. Applications to plywood bonding and laminated structures, plastic preforms, resin bonded paper stock.

454. Pinder, E. Elect.Engng, Feb.1947, 66, 149-160
INDUCTION AND DIELECTRIC HEATING. After outlining the fundamental principles of induction and dielectric heating, the author describes various general types of operations where induction or dielectric heating can and is being used to save time, cost, equipment and/or material. Some data on the type and sizes of units to apply is given.

455. Wetzlar, Isidore Fr.Pat.937,267 12 Aug.1948
DRYING STARCH AND THE LIKE BY HIGH FREQUENCY INDUCTION HEATING.

456. Witsenburg, E. C. Tijdschr.Ned.Radiogenoot., Mar.1948, vol.13, 51-66
HIGH-FREQUENCY DIELECTRIC HEATING. The power developed, potential gradient, frequency and rate of temperature rise in dielectric heating are calculated. Applications to the preheating of bakelite and vulcanizing of rubber are described. Heating of homogeneous dielectrics in parallel is considered, and the theory applied to the rapid gluing of wood using dielectric heating. The glue is selectively heated to over 100°C while the wood only heats to about 50°C. Heating of dielectrics in series is considered, and a plywood gluing application described. Combined series and parallel dielectric heating is used for gluing thin wood sheets to thick wooden bases, utilizing a grid with alternate positive and negative electrode strips. Temperature measurements are taken by a needle type thermocouple indicator. The voltage distribution in the workpiece is deduced. For long wood beams, electrodes should be $\ngtr$ 50 cm apart. Alternatively the electrodes are spaced at a distance < $\lambda/4$ along the beam and tuned by parallel inductors. Matching the workpiece circuit to the valve generator by series capacitors or parallel inductors is discussed and suitable valve generator circuits given.

457. Yarsley, V. E. Plastics Applied 1946 Nat.Trade Press Ltd.p.298
Assemblies of great thickness, especially laminated resin bonded shapes, other than flat, are dried by H.F. 1 B.O.T. unit will heat 1 cubic foot of wood through 100°C. The adhesive has a higher power factor, and gets 5-15 C$^{\circ}$ hotter. A recent development is a 50 watt unit for spot or tack gluing. For flat specimens other heating methods are used.

INFRA-RED (RADIANT) HEATING

General Principles

458. Ministry of Aircraft Production — R.T.P./T.I.B.3.Bibliogr.No.114, 1945
INFRA-RED HEATING, BIBLIOGRAPHY.

459. ----- — Chem.Eng.Handbook 1951 Perry
RADIATION FROM SURROUNDINGS. Theory and Equations.

460. Bieler, G. — Verre Silicates Industr. 13 (211) 1948
Br.Cer.Abstr.48 (4) 1949
DRYING CERAMIC MATERIALS BY INFRA-INFRA-RED HEATING. Most valuable wavelengths are 12,000 to 15,000 Angstroms. Gas radiants can release 90% of their energy in this range, whereas tungsten filaments release only 73%. Heat reflection data for pure Kaolin. Absorption depends on colour. White reflects up to 90%. Review of experience.

461. Burlando — Ric.Scient.Ricos.17 1376-1382 1947 B.I. 432.Sept.1948
Best conditions for hardening synthetic resins etc. Maximum reflecting power for sources of infra-red. 80%-90% obtained by the use of powdered Aluminium, Lead and Magnesium carbonates and Zinc Oxide and lime when wavelength is 1 micron. Thermal efficiency for different materials. Effects of distances and comparison with oven drying.

462. Cowling, T. G. — Reports on Progress in Physics 9 29-41 1942-3 (Physical Society, G.B.)
WATER VAPOUR: FOR INFRA-RED ABSORPTION. The internal motions of the water molecule, absorption and emission, line breadths, absorption by a line spectrum and its variation with temperature and pressure, and steam absorption are discussed, and observations of the total absorption, and the absorption at different wave lengths of damp air are reviewed.

463. Déribéré, M. — Chim.Anal.,1947,29,34-35 (through Chem. Abstr.,1947,-41,2615)
WATER: EVAPORATION UNDER INFRA-RED RAYS. Pure water, copper sulphate solution, and zinc nitrate solution were exposed to light from a Mazda infra-red lamp. The rise in temperature was measured at frequent intervals and the evaporation determined by measuring the drop in the meniscus of each liquid. The rise in temperature was almost the same in each case, and the rate of evaporation was practically proportional to the temperature, being a function of the absorption of the rays. Addition of a drop of oil, petroleum, etc., had scarcely any effect, contrary to the theory of progressive evaporation from the ocean in the absence of rain being influenced by a unimolecular surface layer.

463a. Déribéré, M. H. Dunod et Cie 2nd Ed. Paris 1947
APPLICATIONS PRATIQUES DES RAYONS INFRA ROUGE.

464. Fishenden, M. Mech. Wld, 1946, 119, 220-4
Saunders, O. A.
HEAT: CONVECTION AND RADIATION. Radiation from black surfaces and gas radiation are discussed and curves given showing coefficients of radiation at various temperatures and showing emissivities of carbon dioxide and water vapour. The relative importance of gas radiation and of convection is illustrated by means of a series of charts.

465. Garber, H. J. Ind. Eng. Chem. 42 (3) 456-463 March 1950
Tiller, F. M.
INFRA-RED HEATING. Previous paper dealt with heating of thin panels. Present article gives results of recent theoretical and experimental investigations into heating thick objects with low thermal conductivities in which temperature distribution is non-uniform during transient and steady state periods. Charts are given and the use of Infra Red for heating materials of low thermal conductivity are discussed. 3rd paper, a mathematical analysis, will be presented for heating thick solids of low thermal conductivity. The equations derived in the 3rd paper are summarised in the form of a Fourier series in the present paper. Simplified graphical solutions are presented for temperature v/s time, at top middle and bottom of slab radiated. With high intensity it is possible to obtain a high temperature at the surface for a short period without elevating sub-surface temperatures. The production of this "skin" effect opens the possibility of baking high temperature finishes on wood and related low conductivity materials without dissipating heat or buckling. A review of metal heating is also presented.

BIBLIOGRAPHY

Ernst, R.C. Schumacher, E.F.	Ind. Eng. Chem. 36 1132 1944
Olsen, F. West. Cartridge Co., W.	U.S.P. 2,349,300 23.5.1944
Partee, W. W.	U.S.P. 2,228,585 30.6.1942
Gray, M. G.	U.S.P. 2,341,161 8.2.1944
Piou, H.H. Private Comm.	Burroughs Glass Co. St. Louis. M.
Tiller, F. M.	Chem. Products. Ldn. 8 35. 1945
Tiller, F.M. Garber, H.J.	Ind. Eng. Chem. 34 773. 1942
Tiller, Garber and R. Mackey	Unpubl. Manuscript

66. Gas. Res. Board. British Plastics: 18 144-149 1946
Joint Res. Cttee.
RADIANT HEATING. THE PROCESS AND APPLICATIONS. Emission, and Transmission Characteristics of industrial plastics, are studied. Results show that opacity must result in surface absorption of the radiation, irrespective of wave length; hence the quality of the radiation is of no consequence. Where material is appreciably

transparent, the wave length is important, and thé processes generally favour longer wavelengths as with low intensity dull emitter gas panels or high intensity surface combustor units. Laws of radiation and absorption are appended.

467. [illegible] S. L. Thesis. Textile Research 13 No. 10 18–28 Aug. 1943
INFRA-RED DRYING OF TEXTILES. Literature Survey Concludes that the present infra-red ray gas generators depend for their drying properties mostly on convected heat, but provide a useful source of drying. Drying equations are given.

468. Greenler, H.F. O'Neil, F.J. Textile Res. J. 17 63–68 1947 BII 398
Sept. 1948
RADIANT ENERGY REFLECTANCE OF MEN'S WEAR COLOURS. Data are tabulated for visible energy, infra-red and radiant energy reflectances and Munsell notations of 67 colours. The bearing of the results on coolness of the wear is discussed.

469. Hayman, R. F. London South. Dist. Jun. Gas Assoc., 15/11/46
RECENT DEVELOPMENTS IN RADIANT HEATING FOR INDUSTRIAL PROCESSES. Radiant heating, or the transmission of radiation direct from source to a receiver through air, is effected by gas in two ways:-

(a) by medium temperature black emitter panels, over a range of 230^{o}–340^{o}C.;
(b) by high temperature incandescent sources over a range of 600^{O}–$1,000^{O}$C.

The heat transfer is between 4,000 and 50,000 B.Th.U/sq. ft./hr. Standard types and designs of heating systems are described, as well as experimental models, and the use of insulation by lagging and buffer plates. Heat losses by convection are expressed as

$Q = A(t_o - t_a)^{1.25}$ where
Q = Heat loss by convection from object in B.Th.U/sq. ft./hr.;
A = Convection coefficient;
t_o = Temperature of object ^{O}F.;
t_a = Temperature of ambient air ^{O}F.

Energy radiated by a body is proportional to the fourth power of the temperature, as opposed to heat transfer by convection, which varies almost directly. So the effects at low temperatures are not nearly so marked, and up to 350^{O}C. little advantage is obtained over the convection method. Radiant heating is used in metal finishing, paint curing, plastics, textiles and ceramic drying. In the last named, a wide range of materials from electric railway insulators to building materials has been covered, and it has been shown that the mechanism of drying, i.e. constant rate period and falling rate period, is independent of the drying agent. With radiant heat drying, increasing the air velocity may decrease the rate of drying because, while the energy input is free from gas film resistances, an increase in air velocity increases the convection heat transfer coefficient, and so increases heat loss by convection. Small ceramic objects can be dried in much quicker time than with convection methods. Cracking has always resulted so far with large solid blocks of material, and it is possible that a mixture of convected and radiated heat would be more suitable for them. The limiting factor is wall thickness, which to date is not more than 1-1½ in. There is clearly a wide field of application even within these limits.

470. Jensen, H. H. K.Danske Vidensk.Selsk.Mat-fys.Medd., 1948, vol.24, (8), 26pp.)
SOME NOTES ON HEAT TRANSFER BY RADIATION. The heat transfer by radiation between two bodies at different temperatures, one body entirely surrounding the other, is investigated theoretically, with special reference to the dependence on the form and mutual position of the bodies. Integral equations giving the net loss of energy H are derived for both "grey" surfaces and the general case. An approximate solution of the equations and a formula for H are obtained for "grey" surfaces and applied to two spheres, a plane disc inside a sphere, and two infinite circular cylinders. The effects on H of the non-validity of Stefan-Boltzmann's law and of the cosine law for reflection both at the inner and outer surfaces, and the variation over the surface of the temperature and emissivity of the outer body, giving the resultant radiation field within a closed cavity, are considered. The equations determining the apparent emissivity of a cavity are obtained and solved for a cavity shaped as a spherical cap.

471. Khudyakov, G. N. Izvest. Akad. Nauk., 1946, No. 4, 533-41; Brit. Chem. Digest, Jan. 1947, 1, 146-7
SURFACE EVAPORATION BY RADIANT HEAT. Evaporation from the free surface of a liquid by radiant heat from above has been investigated and an expression for the rate of evaporation G, weight per unit area per hour, in the form $G = Kps/p$ has been developed where ps is the pressure of saturated steam at the surface temperature, p is barometric pressure and K is a constant for each liquid. It was also noted that absorption of heat by each liquid was different.

472. Lowson, J. C. Fuel and the Future 1948. pp. 246-253
THE ELECTRIC INFRA-RED PROCESS. Basic Principles. Curves of Temperature Cycles, Spectral Emission. Characteristics of the lamp radiator, Fuel economy. Typical profiles and diagrams of arrangements of lamps. Applications.

473. Lykov, A. V. Isvest. Akad. Nauk SSSR Otdel. Tech. Nauk. 9 Sept. 1949
THEORETICAL PRINCIPLES OF DRYING POROUS BODIES BY MEANS OF INFRA-RED RAYS.

474. Mackadam, A. C. F. Jnl.Inst.H. & V.Engrs.13 129.38-89
Janser, A. M. J. May-1945

SPECIFIC EFFECTS OF INFRA RED. A survey of basic principles and results of laboratory research up to date. A consideration of some specific effects; a review of problems as they appear at present. Some indications of the use and value of this information for the heating engineer. An initial assessment of present day trends and practices, recommendations for future research. Radiation vs. convection, industrial applications, 35 curves on fundamentals and comparisons. Very clear exposition.

475. Mackey, C. O. Cornell Univ.Expt.Stn.Bull.No.33,16pp.
40 cents; Heat.and Vent.Mar.1945,42,
No.3,104

RADIANT HEATING AND COOLING PART III. The booklet is devoted to a discussion of the thermal environment and radiant heating, and discusses heat transfer by convection and by radiant heating, heat loss by evaporation or moisture, followed by a practical discussion of operative temperatures as originally introduced by the John B. Pierce Laboratory for Hygiene. The author has developed a nomographic chart for determining the operative temperature when the mean radiant and air temperatures and air velocity are known. Following the presentation of this chart the method of heat balances, treated by Professors Raber and Hutchinson in previous papers, is discussed, together with the calculation of an actual example of determining the various temperatures involved and which require the solution of a large number of simultaneous equations. A comparison of the advantage of floor vs. ceiling vs. wall radiant heating is presented, and the effects of cold windows discussed.

476. Malins, E. C. Elec.Review 135 370-72,1944

FULL EMITTER ELEMENTS. APPLICATION TO INFRA-RED HEATING. Heating effect depends on wavelength. Long wavelengths are best for thick sections, such as pottery. Preheating is advisable for mixed materials of varying conductivities. The wave length can be shortened at the last stage of drying at higher temperatures. Reflectors are discussed. Chromium is suitable at 3 microns.

477. Manders, Th. J. J. A. Philips Techn.Rev.,1947/48,9,249-256

DRYING LAMPS: PROPERTIES AND APPLICATIONS. Some of the properties of infra-red radiation are briefly discussed, in particular the absorption of infra-red rays in a layer of water and their behaviour towards lacquers. The requirements to be fulfilled by an infra-red drying lamp are considered and the latest type of Philips drying lamp and its properties are described. Applications of drying lamps to the drying of lacquers, textiles and paper are indicated.

478. Piraux, H. Paint. Pigm. Vern., Mar. 1944, 20, 74-5 Chim. et Industr., May 1944, 51, 93D

DRYING BY INFRA-RED LAMPS. The author explains the choice of a practicable range of wavelengths for drying and shows how the characteristics of lamp for a given radiation may be determined.

479. Ribaud, G. Energie 31 (32 and 33) pp. 57-63 92-94

TRANSMISSION DE CHALEUR PAR RAYONNEMENT DANS LES FOURS INDUSTRIELS.
A treatment with numerous curves of the radiation of furnace flames. Emission, transmission and absorption.
Conclusions:- The addition of a little benzole, tar etc. to produce cracking and incandescent carbon particles can increase the emission factor from 0.15 to 0.40. Other conclusions. The article has reference to high temperatures e.g. in steel furnaces.

480. Roberts, A. L.
Long, R.
46th Report of the Joint Research Committee of the Gas Research Board and the University of Leeds, 1945

FIRST REPORT ON RADIANT HEATING. The basic principles of the utilisation of radiant energy for heating purposes are dealt with and the fundamental differences between radiation and convection methods are shown. The dependence of quantity and quality of the radiation on the temperature and nature of the emitting source is considered with special reference to materials which radiate selectively. A description is given of the spectrometer and the technique of determining emission and the absorption characteristics of various industrial materials. The results are given of the preliminary and general survey of the emission characteristics of typical refractory materials from which the radiating surfaces of high-temperature gas-heated units are usually made. The results of a study of the transmission characteristics of representative stoving enamels are also given. The mechanism of the radiant-heating process is discussed with particular reference to its limitations. The infra-red spectrometer used in this work, and the technique of determining emission and absorption characteristics of various industrial materials are described. Wave length is probably of no significance in paint drying, but dull emitter sources are preferable for plastics.

481. Roberts, J. K. Blackie 1940 3rd ed.

HEAT AND THERMODYNAMICS. pp. 378-421. Mathematical and physical treatment of radiant heating.

482. Raber, B.F. Hutchinson, P.W. Heating Piping & Air Cond. 16, 530-532.9/ 1944

SIMPLIFYING THE CALCULATIONS FOR EXCHANGE OF RADIANT HEAT.

483. Sauter, O. Bull.Ass. Suisse.Electr. 34 107-111. 10. 3. 1944 Sci.Abstr.A. 47, 232. 1944
HEAT RADIATION. Summary of Important Practical Laws.

484. Tiller, F. M.
Garber, H. J. Ind.Eng.Chem., 1942, 34, 773-781
INFRA-RED RADIANT HEATING. A theoretical study is made of the use of infra-red radiation for heating and expressions are deduced for the variation of temperature with time in thin metallic bodies, the maximum temperature attained, and the performance ratio of radiant heating (sensible heat retained divided by total radiant energy striking the stock). Measurements on test panels of cold-rolled steel having thin coats of paint are discussed. Good agreement was found between experimental and theoretical time-temperature curves. Absorptivity curves, energy-time curves, and curves showing the effect of air temperature on performance ratio, and the interrelation of performance ratio, time, temperature and intensity are given. Industrial uses of infra-red radiation and industrial equipment are described, and the design of radiant heat ovens is discussed. See also under Garber & Tiller.

485. Yarham, E. R. Industr.Gas, June 1948, vol. 26, (12), 15, 29
HEATING AND DRYING BY RADIATION IN BRITAIN. The results are given of tests made in co-operation with the Gas Research Board to study the mechanism of the process of paint stoving by radiant heating, particularly in relation to the effect of the wave length of the radiation employed upon the reflectivity of different paint coatings. The results show that with a source of radiation of the electric infra-red type enamels of different colours have widely different absorptivities and consequently paints of the same type but differently coloured will stove at different rates under the same intensity of radiation. With gas heated sources which provide radiation of longer wave lengths, the variation in colour of the enamels has much less effect upon the rate of heating, which is of considerable advantage for practical paint-stoving operations. The infra-red transmission characteristics of a range of plastics in sheet form at wave lengths up to 5μ are also recorded, and show that in all cases the bulk of the transmission occurred at wave lengths below about 3μ.

General Applications

486. INFRA RED HEATING
See also under individual material headings, and under:-

Equipment, general	L. C. B. Frost
Agriculture, potatoes	Mapson. Wagner
Textiles	Preston & Chen.
"	R. H. Wilhelm, G. T. Paul

and under Leather, Orange Juice,
Penicillin and Carpets (Textiles)

487. —— B.I.O.S. Misc.Ref.55
INFRA-RED REFLECTANCE OF COLOURED TEXTILES AND OTHER MATERIALS. The I.R. Reflectance of textile materials dyed with various dyestuffs is considered from the point of view of military camouflage. Details give of methods of manufacturing dyestuffs.

488. Anon. Coke, Dec. 1946, 8, 262-4
RADIANT HEATING APPLIED TO DRYING. Fundamentals are discussed in relation to equipment for the drying of painted articles and other materials. A typical arrangement of luminous-flame burners and diagrammatic layout of pottery drying plant are included.

489. Anon. Engineer 177 71 1944
INFRA-RED HEATING EQUIPMENT, APPLICATIONS. Application to Aircraft finishing. Automatic timing devices.

490. Anon. Coke and Gas, July 1947, 9, 189-91
INFRA-RED HEATING BY GAS. The exhibition held by the British Gas Council at Gas Industry House in June includes demonstrations of the application of infra-red radiation to industrial processes. To obtain full advantage of the fundamental asset of this method, namely the instantaneous transmission of radiant heat from the installations - best advantage is saving in drying time, reduction of time taken in rubber processing from 1-3 weeks to 20 minutes. Describes two kinds of lamps and gives examples of field of use for infra-red heating.

491. Anon. "Times' Review of Industry, July, 1947, pp. 18-19
GAS-FUELLED INFRA-RED HEATING EQUIPMENT: SURVEY. The advantages of infra-red heating methods in industrial drying processes over convection-heating are outlined. These are mainly reduction of drying-time, factory space economy, and smaller bulk and size-adaptability of equipment. Progress in gas-fuelled equipment is reviewed. The advantages of the conveyor method over batch-heating are enumerated, and methods of conveyance and types of belts and supports are discussed, with a special reference to flexible tubes. Various designs of heating surfaces and ovens are described, and the newer rectangular panel heaters are favourably contrasted with cylindrical installations.

492. Anon. Engineer 188 4892.501.1949
INFRA-RED BAKING OVEN FOR MOTOR STATORS. Description of gas heater equipment installed by Tilling Stevens Ltd.

493. Anon. International Chem.Eng.& Proc.Ind.
29 10 450-452 Oct. 1948

DRYING. Modern trends, Away from electric to gas. Matter of price and convenience. Examples:- speed in motor car body drying 2000 cft. gas per min. for painting waggons at R.O.F. Dolmuir. Textil and Paper. Infra-red electric lamps are firmly established. Texts at Vezal Institut Delft shewed that there were no adverse effects on dyed and undyed wool, cotton, linen and rayon fabrics. In U.K., yarns on spools are reduced by I.R. from 4-16 hours to 1 hour in continuous band. In paper making viscosity of water is reduced and it can be more easily pressed out at the last stage of wet pressing. Use in Boot and Shoe soles etc. 30 mins. to 2 mins. and so eliminates dead space in factory. In paper mill; after drying of paper used 18.5 K.W. for resistance elements, but only 4.5 K.W. for Infra-red lamps.
For Gran I.R. gave same yield as coke fuel but better quality.
Possibility for barley has been discussed.
Description of Car body stoving plant.

494. Anon. Heat.Pip. Air Condit., Apr. 1946 18, No.4, 105

RADIANT HEATING DESIGN AND APPLICATION. The basic principles of of radiant heating, especially as they differ from the common types of convection heating, are briefly mentioned and the effect of the rate of body heat radiation, which may be brought about by maintaining warmer surface temperatures of surrounding walls, even in relatively cool air, is pointed out. Principles of application with respect to materials, pipe locations, control systems, expansion, venting, draining, heat transmission and pipe spacing are briefly mentioned. Two methods for calculating ceiling panels and pipe sizes, etc., are given. These involve the use of a number of charts and tables which have been reprinted from the ASHVE Guide and from papers published in Heating, Piping and Air Conditioning.

495. Andrew, L. W. Engineering 1943 156 245-6 298-300
Chamberlain, E. A. C.
RADIANT HEAT APPLIANCES AND INDUSTRIAL APPLICATION.

496. Andrew, L. W. Gas Journal 242 (110) 140 1943
Chamberlain, E. A. C.

INFRA-RED BY GAS. Data are given on the radiation and convection occurring in infra-red drying, chiefly from standpoint of drying paints etc.

497. Appleton, W. G. J. J.Inst.Production Engrs.Oct.1946,25, 265-289

MODERN DRYING PRACTICE WITH PARTICULAR REFERENCE TO RADIANT (INFRA-RED) HEATING. The theory of infra-red or radiant heating is explained, and this form of heating is compared with other systems which have been used in industry for many years. The infra-red system is efficient and economical where parts of plain section, light gauge, and identical shape are to be stoved, particularly when a sprayed coating is to be dried, but for parts of intricate shape and of varying or heavy section, a well-designed air-circulated drying system is better. Generally speaking, a forced convection stove gives better results with dip-coated parts than a radiant type unit. Gas and electric radiant plants are compared; the author favours the former, which has higher energy densities, uses a cheaper fuel, and is more flexible from the control point of view.

498. Barber, I. J. Pulp and Paper Mag. Canada, 1948, March, p.79 (through Papermaking Abstr., 1948, No. 1,22)

PAPER: DRYING BY RADIANT ENERGY. It is pointed out that there are one or two by-products of radiant heating not yet fully utilised, viz., the protection of the outside film of any drying product by a controlled ambient, and the control of radiation under various circumstances. A great gap exists between the basic knowledge of the differences in processing paper products by the infra-red system and the conventional means of operation. Details are given of a test carried out to determine quantitatively on two different types of commercial paper to what degree and depth radiant energy penetrated the paper in a typical application. From the results it appears that the effect of radiant heat at a depth of ½ inch. was approximately 25 per cent. that of conductive heat. Radiant surface temperatures of the same level produce higher temperatures ¼ inch down than conductive sources produce. The results indicate further that the temperature differences are proportional to the number of interfaces.

499. Bates, P. G. Australasian Engr. 43 61-2-3 March 1950

APPLICATION OF INFRA-RED TO INDUSTRIAL HEATING. The hastening of paint and textile drying.

500. Birdsall, G. W. Steel, 6 Aug. 1945 117, 116-119, 148-156; Bull. Iron Steel Inst. 1945, No. 119, 13A.

HOW TO GET THE MOST FROM INFRA-RED HEATING, DRYING, BAKING. The principles of infra-red-ray heating are explained and its application for drying painted and enamelled articles is described with notes on factors which increase the efficiency of the process; such factors include enclosing the lamps and work in a chamber to prevent heat being lost by convection currents and having a holding zone with a much smaller number of lamps than in the heating zone. Conveyor systems for carrying the work between banks of lamps are also described.

501. Carne, J. B. Gas J.,246,435,1945; Gas World,123,296,1945

INFLUENCE OF NATURAL CONVECTION ON THE EFFECTIVENESS OF RADIANT INFRA-RED HEATING. Attention is drawn to the necessity of considering the convection loss from heated objects during infra-red processing. The dependence of the magnitude of this loss on the curvature of the surface of the object, and its relatively greater magnitude for sharply curved objects, are pointed out. The results of an experimental investigation of the effect are detailed; these confirm deductions from published heat transfer data. It is concluded that high-temperature air is essential to the economic heating of sharply curved objects, and to the attainment of uniform temperatures, where objects of various curvatures or differing absorbing properties for the radiation employed are heated simultaneously in the same oven. Suggestions as to the form of test objects used in measuring the performance of radiant infra-red ovens are made.

502. Carne, J. B. Fuel Sci.Pract.,26,90,1947

THE ROLE OF CONVECTION IN MEDIUM TEMPERATURE PROCESSING WITH SPECIAL REFERENCE TO ITS INFLUENCE ON THE DESIGN OF "INFRA-RED" OVENS. An analysis of heat-transfer rates for convection, forced convection and infra-red ovens contrasts the "impeder" role played by convection in the last-named, with its contributory effect in the other two types, and it has been found that convection may cause considerable unevenness of temperature of the article being processed. Experiments showed that the equivalent radiant temperature of the oven was considerably below that of the radiating elements, and that the equilibrium temperature varied with the orientation of the object. Coefficients of natural convection of spheres and vertical short flat plates were re-determined, and the data obtained showed that the limitations set by the "impeder" role of convection depend on the geometric form of the surface of the object and on oven conditions. The role of hot air, considered as that of an insulating agent, suggested that an economic processing system would be one in which the article is rapidly heated to processing temperature by radiation and maintained for the requisite period in equally hot air. A vertical-type conveyor oven has been produced which uses this method with success. (20 figs.)

503. Carne, J. B. Metallurgia,36,193,1947

"INFRA-RED" HEATING BY GAS-ITS DEVELOPMENT AND PRACTICE TO-DAY. Speed of production during the war established the practice of infra-red for industrial usage. Non-luminous radiators suitably designed are adequate for the infra-red range of processing. Two principal features common to British units are the transformation of a high proportion of heat of combustion into available radiation, by causing flame gases to raise the temperature of a metal sheet or plate, which then becomes the radiator, and the discharge of flue gases from the unit outside the heating zone. Advantages of infra-red are a greater speed of heat transfer compared with that of convection, and the degree of reflectivity for the radiation incident on the object where metal objects are subject to heating. Temperature differences of 80°F. entirely due to colour difference of paint have been noted. Up to 80% of the time usually involved in a process may be saved. Simultaneously with the absorption of heat by radiation there occurs transfer by convection, mainly a loss of heat from the article, which increases as the temperature difference between the surface of the article and the ambient air increases. It is desirable that an infra-red system should provide a high air temperature in the heating zone. (4 figs., 1 table.)

504. Clauser, H. R. Materials and Methods, Oct. 1946, 24, 910-914
DRYING INDUSTRIAL FINISHES ON METALS. This, the first of two articles on heating methods for curing industrial finishes, discusses the merits of infra-red heating. The applicability of infra-red heating for any finishing job depends on the shape of the object to be finished, the colour of finish, processing temperature, time, investment, and spare requirements. The mechanism of curing of finishes is discussed.

505. Connell, L. F. C. G.E.C. Jnl. 13 10-32. 1944
RADIANT AND INDUCTIVE HEATING APPLIANCES. INDUSTRIAL APPLICATIONS. The characteristics of the various methods of heating are discussed and the various applications are given.

506. Connell, L. F. C. Trans. Inst. Rubber Industr., 1946, 21, 285-97
INFRA-RED RADIATION AND ITS APPLICATION TO INDUSTRIAL HEATING PROCESSES. A review and discussion, with diagrams and photographs, under the subjects of methods of heat transfer, principles of radiant heating, lamp heating equipment, sources at temperatures lower than that of the lamp filament, and the place of radiant heating in relation to other methods of heating.

507. Déribéré, M.
APPLICATIONS OF INFRA-RED HEATING. See under Food.

508. Déribéré, M. Chimie et Industrie, June 1941, vol. 45, 541-550
USES OF INFRA-RED RAYS FOR INDUSTRIAL DRYING. The efficacy of infra-red drying and its application to industry are discussed.

509. Déribéré, M. Bull. Assoc. Chem. 61 88-93 1944
APPLICATION OF INFRA-RED TO BEET PULP.

510. Déribéré, M. L'Industr.Chim., 1945, 32, 259
DRYING OF DIATOMITE BY INFRA-RED RAYS. It was found that dry diatomite behaves rather as a reflector of infra-red rays. However, the wet powder is far more absorbent, and if infra-red drying is used the high reflectivity will become operative only towards the end of the drying operation. Since diatomite is so poor a conductor of heat it must be spread in thin layers if it is to be dried economically by this method; it was found that the optimum thickness of such layers is 3 cm. A drying tunnel 33 ft. long and 3 ft. wide operating for 12 hours daily should dry over 2 tons of diatomite a day, from an initial water content of 40% to a final water content of 5-8%. It is estimated that the power consumption would be 62.5 kw. Trials have shown that drying at 60°-70°C. with infra-red lamps is more rapid than drying at 80° C. with hot air.

511. Déribéré, M. L'Industrie Textile 63 246-249 1946
SIZED WARPS AND INFRA-RED DRYING. See under Textiles.

512. Déribéré, M. Rev.Gen.Elect.Feb.1947, 56, 71-4
SOME APPLICATIONS OF TREATING, DRYING AND BAKING BY INFRA-RED RADIATION LAMPS. A review covering applications to the drying and baking of paints and varnishes, and the drying of leathers, wools and felts.

513. Dixon, A. G. Heat.Vent., Dec. 1946, 43, No. 12, 59-64
WILL RADIANT HEATING DISPLACE CONVECTION HEATING? The growth in popularity of radiant panel heating is traced and the advantages claimed for it are discussed. It is maintained that these advantages are over-rated and that convection heating is more comfortable and efficient.

513a. Duchene, R. Genie Civil, 1 Apr. 1946, 84-5; Motor Industr.Res.Ass.Abstr., June 1946, No. 2920
DRYING WITH INFRA-RED RAYS FROM RADIATING TUBES HEATED BY COAL GAS. When paints or other substances have to be dried, the essential problem is to provide sufficient heat for evaporation to occur freely. The method of heat supply can generally be classified as by convection or by radiation. In the former process, heat is always transferred primarily to the actual surface layer of the member to be dried, with the result that any increase in drying rate is limited severely by the high temperature that will be taken up by this layer before an increased conduction rate to the rest of the material can be established. To overcome this difficulty, drying by means of infra-red radiation has been developed in America and England. The essential advantage of this method is that the rays can penetrate an appreciable depth below the surface before giving up their heat.

513b. ——— Electricité 34, 162, 153-4 June 1950
DRYING OF MAGNETIC RECORDING TAPE BY INFRA RED AND A DISCUSSION OF HEAT REQUIREMENTS.

514. Eeles, C. C. Gas J. 5 and 12 Sept. 1945, 246, 339, 341, 375
INFRA-RED VERSUS CONVECTION HEATING. The author reviews the characteristics of convection and infra-red heating as applied to the drying or baking of industrial finishes in continuous ovens. Infra-red, in his opinion suffers from various disadvantages due to e.g. shadow effects, shape and cross-section of objects, local overheating, difficulty of vapour removal etc. High speed convection heating, he considers is more flexible, quite as rapid, and more satisfactory in performance and efficiency than infra-red heating.

515. Estes, D. F. and Potter, A. L. Elect. World, 15 Sept. 1945, 124, No. 11, 148, 150
INFRA-RED LAMPS DRY COAL TRANSFER BELT. Each year the Rail to Water Transfer Co., Chicago, tranships some 2,000,000 tons of coal from rail cars to cargo boats plying the Great Lakes. Coal is transferred customarily, by dumping it from hopper cars on to a 54-in. conveyor belt that carries it up a 300-ft. incline where it drops by chute into the hold of the lake vessel. When edges of the rubber covered belt become frayed and fabric plies separate, speedy repair is essential. Drying of the belt fabric is necessary before the separated canvas plies can be recemented. An infra-red channel, consisting of 20, 250-watt, R-40 reflector lamps on 6-in. centres which will dry a 15 to 20-ft. section of belt uniformly in about 1/2 hr. is used. This length is the longest that can be properly repaired at one time. This installation has been used to effect a 4 hr. cure of the rubber cement and coating as well.

516. Faber, F. H. Amer. Gas Assoc. Mon., Feb. 1945, 27, 89-91
GAS IDEAL FOR BAKING AND DRYING. A description is given of the development of infra-red heating from the early open lamp installations, through uninsulated and insulated systems, to the Convect - O - Ray system in which the amount of air needed for ventilation is introduced at a predetermined temperature into the infra-red oven, and the "Surg Bake" or surge baking system, according to which the oven temperature is surged to make the metal temperature of the sample follow a predetermined curve.

517. Faber, F. H. Ind.Plastics 1946 1, (8) 24-5 32
CONVECTION OVENS ARE 26% LESS COSTLY THAN INFRA-RED.

518. Gen.Motors Corp. B.P.553,664,1943
DRYING POWDERED MATERIAL. App. for drying granulated insulator material containing resins. Carried on a porous support, exposed to infra-red rays, and to a current of air across and through, and the material is inverted at least once as it passes through the rays.

518a. Hall, J. D. London: McGraw-Hill Publishing Co.,Ltd, 1947, 201pp., 21/-; Mech.Wld, 20 Feb.1948, Vol.123,207
INDUSTRIAL APPLICATIONS OF INFRA-RED. This book describes and illustrates American technique for the production of infra-red rays and their different applications. It is divided into nine chapters and covers the advantages of infra-red heat, the electric infra-red lamp with the equipment wherein it is used, and the various fields in which the rays may be applied, including paint drying, textile drying, processing of ceramics, the drying and softening of plastics, metal working and the skin drying of foundry moulds, and the rapid drying of ink in the printing industry.

519. Hayman, R. F. Practical Engineering, 1947, -15, 208-210
RADIANT HEAT DRYING SYSTEMS. The advantages and limitations of radiant heat systems for drying are briefly reviewed, with special reference to ceramics, textiles, and finishing of metals with paint and varnish coatings. A table shows the performance of black emitter radiant heating tunnels in metal painting.

520. Hayman, R. F. Paper to Fuel and the Future, Min. Fuel Power Conf., 8-10 Oct.1946, 20pp.
TOWN'S GAS FOR DRYING BY RADIANT HEAT. The subject is discussed under the following headings: (1) Principles; (2) Experimental development; (3) Temperature measurement and control; (4) Practical utilization; (5) Future developments and prospects. 22 Refs.

521. Hess, F. O. Amer. Gas Jnl. 172 2.16.42.1950
GAS HEATING FOR PROCESS OPERATIONS. Use of radiant panels for drying ink, for annealing and other processes.

522. Huebler, J. Industr.Engng.Chem., June 1948, vol.40, 1094-1098
RADIATIVE AND CONVECTIVE HEAT TRANSFER RATES PERTAINING TO HEATING PROCESSES. In recent years there has been a great focus of attention upon rapid heating methods employing radiation, convection, and induction. Concrete analyses of the effective value of convection versus radiation are difficult to perform because of the inseparable character of the two phenomena. The present paper seeks to compare, under theoretically ideal conditions, the effect of radiation and

convection heating simultaneously applied to a plate. For this purpose an equivalent radiation "heat transfer coefficient" is utilized, and although the differential equations involved are insoluble graphical methods of solution are applied. The results reveal the contribution made by convection alone to the total heat transfer attainable under assumed conditions and its ratio to heat transfer by radiation.

523. Hughes, H. R. Southern Power and Ind. 1945, 63, No. 3, 92-3, 114: Chem. Abstr. 1945, 39, 1787

RADIANT GAS HEATING FOR INDUSTRIAL DRYING. There is still a very considerable lack of information about practical applications of radiant heating, and new installations must be designed, at least in part, from existing installations rather than from theoretical calcns. At least 40-50% of the heat input into gas burners or electric lamps, is absorbed by the material dried - in the case of paints the colour is an important factor in amt. absorbed. When inflammable vapours are evolved electric lamps are best, while radiant gas heaters are best where large amts. of moisture are to be removed. Applications of radiant gas heating include textile drying, continuous brazing, annealing glassware, processing specially treated paper, textile coatings, etc., and they might well be used for a variety of food-processing operations where an open burner would not be dangerous.

524. Jolly, F. J. Edison Elect. Inst. Bull., Mar. 1948, vol. 16, 77-80

TECHNICAL AID, IMPROVES INFRA-RED PERFORMANCE. Careful investigation has shown that variations in the quality of products submitted to infra-red heating are due to uneven treatment. These are obviated by better arrangement of the heating lamps and by altering the position of the item on the conveyor belt according to its size and shape.

525. Keller, J. D. Industr. Heating 14 568-70-2 574-6-8-584 1947

INFRA RED DRYING. The principles of the method are outlined with special reference to paint. Equipment is discussed.

526. Kodaks Ltd. Ind. Heating Engr. 12 (54) 141-143 Apr. 1950

INFRA-RED DRYING FOR CAMERA BODIES. An illustrated description of process using gas or electrically heated ovens.

527. Van Kampen, G. R. Paper Trade J. 1947, 125, No. 15, 34, 36

INFRA-RED DRYING PLANT: CHOICE OF GAS OR ELECTRICITY. A comparison is made of the number of kilowatts and cubic feet of gas required for removing a given amount of liquid in infra-red drying, and of the respective costs of gas and electricity, at various rates per unit, per 1,000 lb. water evaporated. Choice should be guided by consideration of (1) heat output of the equipment, (2) space required, (3) maintenance, and (4) cost of installation.

528. Landfermann, C. A. Chemie-Ingenieur-Technik. 22(1)5-7. 1950

PROCESS APPLICATIONS OF INFRA-RED. Transl. Title. Description of application to plastics, textiles and pottery.

529. Macadam, A. C. F. Pap. to Instn Engrs-in-Charge; Gas J., 5 May 1948, vol. 254, 272-281

INDUSTRIAL INFRA-RED HEATING BY GAS. Comparative figures are given for infra-red and normal drying methods for many coated materials and for

	Infra-red	Normal
Dipped earthenware glaze	4 min.	40 min.
Electrical porcelain trolley wire insulators	2 hr	24 hr
Ceramic thread guides	¼ hr	24 hr

A table gives black-body emission for the black emitter and the bright emitter ranges. No emitter is as efficient as a black-body; the factor of emissivity of a gas-fired tunnel or flat panel is usually taken as 0.9. The net heating efficiency is usually taken to be 50-55%. Tunnel and flat panel infra-red dryers are described. Clay blocks, 2 ft dia. and 20 lb. in weight were successfully dried in 10 hr with a radiant temperature of 150° C., but this low temperature is difficult to maintain in a gas-fired tunnel and a combination of radiation and convection is recommended with controlled humidity. A unit is mentioned that is being used for fusing a printing ink into the glaze of sparking plugs. A high radiant intensity (50,000 B.Th.U/sq. ft) enables temperatures up to 700 °C. to be obtained. This equipment has also been used for annealing glass cells, which require to be raised from 500° to 650° C. and then slowly cooled to 50°C. Another application is the toughening of glass instrument cover panels by heating to 500° C. and then quenching in air. In the discussion following this paper mention is made of the successful drying of vitreous enamel by infra-red, the drying time being reduced from the normal 12-18 hr to 4 min.

530. MacAdam, A. C. F. Jnl. Heat & Vent Engrs. 13 p.75 5 June 1945

BIBLIOGRAPHY 46 REFERENCES.

531. Merz, A. Stuttgart - Zuffenhousen Werkstoffe u. Korrosion Jahrgang 1950. Heft 6/7 June-July pp. 217-296 in German

EINIGES UBER INFRAROT TROCKNUNG. Description of requirements with particular reference to paints.

532. Metro Vic Prochure 1948
INFRA-RED HEATING. Curves of reflectivity of metals from $10^{2}-10^{5}\bar{A}.^{B}$ Curves of Emission Characteristics. Pictures of Installations.
Applications:- Paint, Printing, Textiles, Powders, Plastics, Paper, Wood Boards, Shoe Cements, Hosiery, Rubber, Mobile Units.

533. Miskella, W. J. U.S.P. 2,474,952 5 July 1949
Continuous dryer for granular materials. An application for drying and heating granular material in a continuously flowing stream consists of a vibrating arrangement for imparting flow to a material down a sloping tray, a plurality of heating lamps so arranged that their rays are directed onto the tray and the granular material passing over it, walls enclosing the lamps so as to form a tunnel-like space with the tray and having reflective surfaces, and a blower to direct a stream of air between the lamps and the tray in order to remove evaporated materials.

533a. Miskella, W. J. Miskella Infra Red Co. Cleveland 1947
INFRA-RED IN INDUSTRY.

534. Paul, S. T. Proc. 7th Ann. Meeting, U.S. Textile Res. Inst., 1946, 37-38
TEXTILES: INFRA-RED DRYING. A popular comparison of the economics and performance of the infra-red drying method of textiles with the hot air and high-frequency dielectric drying methods.

535. Reavell, J. A. Trans. Inst. Chem. Engrs. 22 13-30. 1944.
Industr. Chemist 20 119-130. 1944
INFRA-RED RADIATION: USE FOR EVAPORATION AND DISTILLATION.
Types of Generators, wavelengths, temperature, energy and cost are discussed. Applications for heating and drying. Evaporation and distribution of liquids are studied, and infra-red heating of them is contrasted with methods using steam heated fluids or hot gases. Conditions of heat transfer in evaporators are examined. Satisfactory results in concentration of sensitive solutions are reported. Application to climbing film evaporator.

536. Roberts, T. A. Brit. Plastics, July 1945, 302-5
Happerfield, G. J.
INFRA-RED HEATING. The use of the r.f. method for pre-heating has been widely adopted and the advantages and limitations of this method are summarized. Experiments on the pre-heating of moulding materials by the infra-red method are described together with equipment.

537. Rowland, F. E. Discovery, p.277, Sept. 1944

INFRA-RED LAMP HEATING IN INDUSTRY. Trough reflectors plated with rhodium are an innovation in the use of lamps as a source of radiant heat. The temperature reached in an article subjected to radiant heating is influenced by its composition and the nature of its surface, but with the lamp heating plant at present available maximum temperatures of the order of 600°F. are obtainable in metal articles in a few minutes. The advantages of infra-red heating are discussed for paint drying, coil drying, drying foundry moulds, accelerating the setting of adhesives, processes in the textile industry, and softening plastics.

538. Shuman, A. C. Food Technology pp.481-4 Dec. 1950
Staley, C. H.

INFRA-RED HEATING. Has been successfully applied to the concn. and drying of sugar products, potatoes, toasted wheat germ, bread crumbs and a variety of fruits and vegetables. The authors supply information on the fundamental properties of the radiation. (1) Each layer absorbs the same % of impinging radiation, (2) the % varies with wavelength, (3) the wavelength scale depends upon the temperature of the source. The authors explain how to choose a source for greatest efficiency of operation. The absorption properties of the containers are considered,; nylon or polythene absorb negligible amounts of radiation.

Operating efficiencies average 90% and overall efficiencies, depending upon absorption of the material are generally about 65%. Often cheaper than older methods, because of better control.

539. Stout, L.E. Caplan, K.J. Trans. Amer. Inst. Chem. Engrs.
and Baird, W.G. 25 June 1945, 41, 283-314

MECHANISM AND RATE OF DRYING BY NEAR INFRA-RED RADIATION. This study attempts to illustrate a method of applying the near infra-red drying procedure to a specific chemical. Also, the mechanism of infra-red drying is compared with atmospheric and vacuum drying. In general, near infra-red radiation permits drying at rates which are substantially higher than can be achieved (at similar cake temperatures) by atmospheric or vacuum methods. Radiant energy is merely another and more rapid method of heat transmission, one which is independent of air film or liquid film resistances to heat flow. The mechanism of water flow to the drying surface is not different from that encountered in air or vacuum drying. Specifically, this work shows that under "infra-red lamps" the rate of drying decreases with increasing air velocity and distance from the source of radiant energy. Thickness of the material to be dried has little effect

upon the constant rate period of drying, during the falling rate period, the process is described, in general by the equation $y = cx^n$.
Curves shew relations for sand, soap, stearate. The Drying of T.N.T. and Smokeless powder are included.

540. Tiller, F. M. Garber, H. J. Ind.Eng.Chem. 34 773-81. 1942
INFRA-RED RADIANT HEATING.

541. Tiller, F. M. Chem.Products 1945, 8 35-40; Brit. Abstr.B.I.July 1945, 202
RADIANT HEATING. For efficiency, ovens should embody subsidiary air heating, radiant energy being used only for heating stock. Radiation rates up to 3000 B.Th.U./sq.ft./hr. can then be obtained and radiation can pass through solids to evaporate liquids beyond. Application to specific drying problems is discussed.

542. Tooke and Gatehouse Electrical Review 137-41. 169-72. 1942
INFRA-RED DRYING.

543. Uchastkina. Z. V.
DRYING BOARD WITH RADIANT HEAT. See under Paper and Board.

544. Vanderweil, R. G. Domestic Engng. Jan. 1946 167 No. 1. 104-7, 136, 143, 176
HISTORY AND INTRODUCTION TO MODERN METHODS OF RADIANT HEATING.

545. Walker, Lewis, McAdam, Gilliland Principles of Chem.Eng. 1937 p. 145-167
Radiation (and Heat Losses). Table of results for interchange of heat between various shaped surfaces.

546. Weiss, M. L. Rayon Textile Monthly 24 499-501. 1943
RADIANT HEAT GENERATORS AND APPLICATION.

547. Westbrook, F. A. Textile Manufact., 1946, 72, 589-590
INFRA-RED HEATING APPLIANCES: APPLICATION FOR DRYING. The use of infra-red (radiant) heating to augment the drying capacity of steam-heated equipment has resulted in production increases of 25 to 50 per cent. A number of examples of successful applications of electric lamps and radiant gas burners is considered. In one case three banks of six 500-watt infra-red lamps have been installed in a conventional five-can rayon warp sizing machine. In another plant the drying of each colour after the application of dye in printing cloth bags was accelerated by 50 per cent by adding infra-red lamps to supplement the steam heat of an otherwise satisfactory machine. Other cases include the fitting of

three banks of infra-red lamps in front of a calender, the use of radiant heat gas burners with tenter dryers and with automatic control instruments, gas infra-red generators installed on tape frames, and the use of gas burners for singeing.

548. Zimmerman, G. Travaux de Chimie Alimentaire et d'Hygiène 37(1/2)35-7.1946
Adaptation of Infra-red for drying feeding stuffs and food materials. A very informative paper. 30 References.

Equipment General

549. Anon. Engineering, 1948, 165, 403, via J. Text. Inst., 1948, 39, 310A. June, 1948
INDUSTRIAL APPLICATION OF RADIANT HEATING UNITS. The construction, fitting, and performance of various commercial radiant heating units is described.

550. Anon. New Zealand Eng. 5 408-412 1950
INFRA RED TUNNELS. Convection and infra-red heating equipment compared.

551. Garve, T. W. Amer. Cer. Soc. Bull. 27 299-300. 15 Aug. 1948
ACCELERATED RADIANT HEAT DRIER.

552. Keller, J. D. Industr. Heat., 1947, 14, 568-570, 572, 574, 576, 578, 580, 582, 584
INFRA-RED DRYING. A discussion is given of the various types of equipment available for infra-red drying ovens, including the electric heat lamps. Comparisons of each type of firing are made, pointing out the relative advantages and disadvantages. A brief summary of factors to be considered in the designing of drying ovens is given.

553. Krupp, P. H. Ohio State Univ. Eng. Expt. Sta., 15, No. 1, 3, 1943
NEAR INFRA-RED DRYING. The design of reflectors and tunnels for the infra-red drying of lacquers etc. is considered.

554. Reavell, J. A. B.P. 572, 113. 3/12/43
INFRA RED DRYING APPARATUS. Generators are heated by liquids or vapours, e.g. Diphenyl compounds at 250-300°C for 4.5 to 5.5 microns; Mineral oils at 300°C for 5 to 6 microns; Nitrite and nitrate mixtures at 200° to 300°C for 3.8 to 6.0 microns Mercury vapour at 500°C for 3.8 to 6.0 microns or electric elements or steam may be used for temperatures up to 150°C for 6 to 10 microns.

555. Westbrook, F. A. Textile Mafr. 1946 72 589-90
INFRA-RED HEATING APPLIANCES. APPLICATIONS FOR DRYING.

Equipment Electric.

556. Anon. Elect.News.Engng, 15 June 1945, 54, No. 12, 91-2
INDUSTRIAL POWER AND HEATING. Canadian Electrical Association Committee. New high-intensity equipment for infra-red heating is available now in Canada. Two installations are described. One oven for drying miscellaneous textile articles is rate at 80 kw, 550 volt and is 20 ft. long by 4 ft. wide. The lamps are 40 kw above and 40 kw below an open mesh conveyor. Another similar oven is rated at 60 kw, 550 volts and is of the horizontal type. Some of the applications of dielectric high frequency heating are also listed.

557. Anon. Ceram. Ind., 39, No. 6, 74, 1942
NEAR INFRA-RED DRYING INVADES INDUSTRY. The Fostoria Pressed Steel Corporation, Ohio, has developed a near infra-red drying system. The drying is accomplished by heat derived from a series of lights placed in tunnels or over conveyors near to the product to be dried. Reflectors are placed behind each unit to direct the heat directly on to the product. The process is an efficient and economical way of delivering heat to the point required.

558. ---- Food Inds. 11(10) 1939
RADIANT HEAT DRIER. Alzac Aluminium reflectors with G.E.C. 250 Watt C.X. drying bulbs, e.g. vacuum drying of food products.

559. Anon. Electricite, Mar. 1948, vol. 32, 62
NEW FRENCH INFRA-RED LAMP. A description of a new tubular 100W. infra-red lamp which is particularly useful for treating substances such as pharmaceutical products, which must be dried at a low temperature by uniformly distributed heat.

560. Attwood, G. U.S.P. 2,405,631/1946
DRYING OVEN. In a drying oven using infra-red lamps for drying the coating of articles, means for arranging a plurality of infra-red lamps in a line approximating the contour of the article being dried, the means consisting of a supporting frame of vertical side members and a cross member, a plurality of short members carried thereby, one of which is fixed in an inclined position to the inner face of a side member and another of which is fixed to the first short member and to the side of the cross member.

561. British Thomson Houston Co. Ltd. B.P.591,190/1947
INFRA-RED BAKING OVENS. An oven suitable for handling articles being moved continuously by a conveyor is described, in which the lamps and sockets are protected from overheating, the heat exchange of the protective system is utilized for heating the work, and inspection and replacement of the lamps is facilitated. It consists of a heating chamber, a series of panels with heating lamps and sockets arranged along at least one wall of the chamber, and an insulating shield, having holes through which the bulbs of the lamps project, spaced apart from the adjacent wall on its inner side to provide an enclosed cooling chamber. Means for forcing air upward through the cooling chamber, past the sockets and through the passages around the lamps into the heating chamber are provided.

562. Déribéré, M. Ann. Chim. Anal., 1943, 25, 34-6
LABORATORY STOVES HEATED BY INFRA-RED RAYS. Six useful drying ovens are shown and described. The heat is derived from lamps emitting infra-red rays and it is possible to dry samples quickly at relatively low temperatures.

563. General Electric Co. Ltd., Brit. Pat., 557,252, 11/11/43
and Humphreys, O. W.
APPARATUS FOR EXPOSING OBJECTS TO RADIANT HEAT. Improved reflectors for infra-red drying are asymmetric, so that at least part of the heat radiation strikes the surface to be dried at an oblique angle.

564. Henki, L. K. University of Wisconsin Jnl. Chem. Ed. 26 512-3. 1949 Chem. Abstr. 44(5) 1763. 1950
INFRA RED DRYING OVEN. Instructions for constructing an oven 24" cube 1000 watts.

565. Lowson, J. C. Fuel and the Future, 1948, 1, 246-254
Incandescent Lamp Infra-red Drying System. The basic principles of the incandescent lamp system are described. The flexibility of the lamp system enables fuel wastage to be reduced to a minimum, and various expedients for achieving this end are considered. Typical infra-red equipments, including multi-purpose tunnels, are discussed. Also Jnl. Iron Steel Inst. 156 134 May 1947.

566. Malims, E. C. Electrical Review 1944 135 370-72
DULL EMITTER ELEMENTS. Application in Infra Red Heating.

567. Metro Vic. Brochure 20 pp. 1948
INFRA RED HEATING. HOURS INTO MINUTES. Illustrations of various units employing lamps. A short account of heat transfer, reflectivity etc.

568. Rowland, F. E. Discovery 1944 5 277-280
INFRA-RED LAMPS. INDUSTRIAL APPLICATION.

569. Seymour, H. Electrician 129 200 1942
INFRA RED BAKING. Lamp and Reflector Design are discussed. Radiant heating has an advantage over convection heating in that very high energy transfer rates are obtained.

570. Sill Paper Co. Textile World, 1949, 99, No. 1, 148
ELECTRIC HEATING UNIT FOR DRYING PLANT. A new heating unit, using electric filaments closely woven among glass fibres, is described and illustrated. The unit is designed to give dry heat up to 700oF. Such heating units in curved sections have been used for supplementing textile drying operations.

571. Egeler, C. E. Purchasing 30, 4, 92-5, April 1951
INFRA-RED LAMPS AT WORK. Applications of infra-red lamps to various processes.

572. Spillran, A. D. Edison Elect. Inst. Bull. June 1945, 13, 159-160; E. R. A. Abstr.
RECENT DEVELOPMENT IN INFRA-RED APPLICATIONS. Gives notes on infra-red lamp equipment and examples of recent applications to manufacturing processes. Expected post-war developments are briefly scheduled.

573. Ware Spools Manufacturing Co. S. Carolina Textile World 1944 94 No. 3. 83
INFRA-RED DRYING LAMPS. APPLICATION IN SIZING.

574. Wiegand, E. L. & Co. Chem. News. 13.9.1948 p. 2722 26 37
ALL METAL ELECTRIC RADIANT HEATERS. Glassless, glareless, high heat intensity. Utilisation of almost entire infra-red band. Designed for baking, preheating, dehydration. Open element, polished aluminium reflector. (Nature of element not stated) Temperatures 1000° - 1400°F.

Equipment Gas

575. Anon. Gas Heat in Industry p. 184-7 March 1949
INDUSTRIAL DRYING PROCESSES. Gas-fired infra-red black emitters are discussed; some advantages are their flexibility and immediate adjustability over the whole working range, and the fact that different temperatures can be maintained in various parts of a drying tunnel or of a series of panels.

A flat panel unit evolved for special manufacturing processes is described and some advantages of this type of tunnel are enumerated. Horizontal flat panel units and their use in conveyor systems are briefly considered.

576. ---- Br. Gas Council Pamphlet 1948
Technical Description of the new gas heated infra-red ovens at the Austin Motor Works for drying painted parts.

577. Anon. Indust. Gas., 20, 27, 1947
INFRA-RED GAS UNIT PANELS. Need for the production of war equipment resulted in the development of two gas-fired units, now commercially available. Features considered basic to the design of these units were simple construction, easy adaptation for assembly in battery, and a gas consumption of approximately 0.1 therm/hr. The low-pressure unit is described in detail, and incorporates a brick, the insulating and radiating effects of which effectively contribute to the maintenance of the radiating element at any mean temperature up to 540° C. This, being a flat surface, emits radiation with an intensity distribution which at 3 ft. follows the natural cosine curve. When operating at 3 in. water gauge under normal installation conditions, heat is radiated from the panel at up to 4,000 B.Th.U./hr. and convected at about 1,500 B.Th.U./hr. The units may be used inclined at any angle within 45° of the vertical, and fields of radiation of unlimited extent can be established to effect uniform temperature over surfaces at all inclinations. An interesting application of the units is to clay gas radiants, the drying of which is speeded up without alteration to existing manufacturing practice. The units are disposed in the drying room so that the clay radiants are weakly irradiated while spread on trays. By this arrangement, which differs from previous practice only in that the trays are in echelon instead of being piled above one another on their racks, the clay is dried to its trimming state in four hours, instead of in an uncertain period from 30-70 hr. The ovens designed for use with the unit take advantage of the fact that a high temperature in the stoving space is essential to effect reasonable uniformity of processing of articles which vary in dimensions. Vitreous enamel frit coatings on sheet iron can be dried at the rate of 600 sq. ft. sheet metal/hr., the passage lasting only four minutes.

578 Anon. Gas J., 253, 524, 1948
A NEW INDUSTRIAL RADIANT UNIT. Gas-fired infra-red heating units are described having the following characteristics:

	Model 1.	Model 2.
Area of emitting surface (sq. ft.)	2	4.25
Average surface temperature (°C.)	340	340
Temperature distribution over whole surface when freely exposed (°C.)	±25	±35
Radiation output (B.Th.U/hr.)	4,500	9,550

The radiation can be from above or below.

579. Anon. Gas Wld, Industr. Gas Suppl.,
20 Mar. 1948, vol. 128, 34

RADIANT HEAT PROCESSING BY GAS: NEW TYPE OF INDUSTRIAL UNIT ENSURES FLEXIBILITY. An illustrated description is given of an industrial radiant unit, rectangular in form and so designed that a number can be built up into a plant of any desired cross section to suit the work to be processed from flat sheets to large and bulky articles of any shape. All components are accessible through the back of each unit when built into the plant. Performance data are given for two types.

580. ---- Nat. Gas Bull. (Australia), Mar.-Apr.,
1946, 10, 22

RAPID RADIANT PAINT DRYING WITH GAS. A rapid radiant gas oven is used for baking industrial lacquer in the factory of Automobile Parts and Accessory Co. Ltd., Adelaide. Heated by two bar burners fitted with Bray jets, it is 12 ft. long with a working space 18 ins. high x 14 ins. wide. Combustion products are vented through damper-controlled outlets at the top of the oven and thermostatic control is employed. The maximum gas rate is 440 ft. per hr.

581. Anon. Brick Clay Rec. 114(4)76. 1949

INFRA-RED TESTS CONTINUE, RELIANCE DRYING LOSSES BELOW 2%. A brief description is given of a new dryer, based on the infra-red principle, and converted from a warm air tunnel dryer; gas burners are placed 3 ft. apart.

582. Anon. Wheelco Comments, 7, No. 3, 2, 1948

INFRA-RED HEATING WITH GAS-FIRED INCANDESCENT UNITS. In a continuous dryer using gas, 85% of the thermal energy is in the form of infra-red rays, incandescent refractory reflectors being used. There is automatic control in case of failure and push-button control for lighting up. Fuel saving is estimated at 20-40% and production rate can be doubled. (2 figs.)

583. Anon. Textile World 93 (1)56-58 60-61 1943

GAS FIRED INFRA-RED UNITS: APPLICATIONS. Gas burning units are less expensive and take less space than batteries of lamps of equivalent capacity. Attempts to measure temperatures of fabric surface shew that they may be as high as 800-1000°F; and apparently this does no harm as long as some water is present. Overheating can be avoided by automatic control. Photographs of installations.

584. Atkin, F. L. Gas J. 1944. 244 371-4 Br. Chem. Physiol. Abstr. 1944 B. 1. 377

INFRA-RED DRYING OVENS. A series of gas fired, radiant heat drying ovens is described and considerable economies over electrically heated units are claimed. Various shapes are described. Panel temperatures of 600°F up to 1600°F and flux densities of 3,000-4000 B.T.U./sq. ft. at the lower temperature. Convection currents make it necessary to reduce radiating temperatures from bottom to top. Applications.

585. Coxon, W. F. Gas Times, 30th July, 1948, vol. 56, 154, 157

RADIANT HEAT DRYING. Details of gas fired radiant tunnel ovens at the Mechanical Handling Exhibition at Olympia are given.

586. De La Rue Gas Development Co. Industrial Gas Times, 1947, 10, 182-186

GAS PANEL INFRA-RED HEATERS. Illustrations are given of various ovens based on unit gas-heated panels, 23 x 12 x 4 inches. Each unit consumes about 0.1 therm per hour at 30/10 in. w.g. gas pressure, emits 4,000 B.Th.U. per hour in the form of radiant heat and dissipates from its radiating surface 1,500 B.Th.U. per hour in high-temperature convected air. The illustrations show a 2-unit oven (the smallest) and a 64-unit conveyor oven for stoving steel sheets.

587. Duchène, R. Genie Civil. 123 84-5 1946 B.I. July 1948

GAS HEATED RADIANT PIPES. Uniform temperature in pipes with flame 3 metres long, 50 mm. diameter.

588. Fitzsimmons, W. A. Gas World, Indust. Gas Supp., 18, No. 4, 39, 1945

TEST DATA ON MULTI-TUBULAR TYPE GAS-FIRED INFRA-RED OVEN. Performance data are given for an experimental infra-red dryer for metal finishes. The radiating source consisted of sixteen 6 ft. by 1½ in. bore wrought iron tubes fixed about a circle 30 in. diam. to form a horizontal tunnel 6 ft. long.

589. Gas Light and Coke Co. Textile Wkly, 1946, 38, 414-416.

GAS-FIRED RADIANT HEATING PANEL. An illustrated description is given of a horizontal, gas-fired panel, 4 ft. 8 in. x 3 ft. 8 in., designed for "curing" fabrics coated with polyvinyl chloride. The panel reaches a temperature of 650° F. after about 15 minutes and fabrics can be "cured" successfully by passage under the panel, 3¼ - 5½ ins. from the surface, at a speed of 2¼ to 10 ft per minute.

590. Geslin, R. Energie, 1948, vol. 32, 141-145; abstr. in Chem. Abstr., 1948, vol. 42, 6177
STUDY OF TEMPERATURE IN FURNACE HEATED BY INFRA-RED RADIATION. Principles of infra-red heating are explained. Curves and diagrams show the best location and spacing of lamps.

591. Hawk, C. A. Power, May, 1946, 90, 307-9, 347b, c, 348a
RADIANT HEATING FOR MODERN CONSTRUCTION. Theory and practice of the installation of radiant heating systems for all purposes is presented.

592. Hayman, R. F. Pract. Engng., 15, 148, 174, 1947
RADIANT HEATING FOR INDUSTRIAL PROCESSES. A description is given of the various types of equipment used for radiant heating by gas. They include black-emitter tunnels for temperatures from 270° to 340° C., and high-temperature incandescent equipment for temperatures from 600° to 1,000° C. Recent experimental development is also discussed. Methods of temperature measurement and control in gas-operated radiant-heating equipment are discussed, and heat loss due to convection is considered. Medium-temperature tunnels and panels used for metal finishing and paint curing are described. (22 figs., 2 tables.)

593. Hayman, R. F. Fuel and the Future, 1948, 1, 254-262
BLACK EMITTER RADIANT HEAT DRYING SYSTEMS. The principles of radiant heating by gas are considered and the practical utilisation of medium-temperature black emitter tunnels and panels is discussed under the headings; (a) Metal finishing and paint curing, (b) Ceramics; (c) Plastics and Textiles; and (d) Other processes. The significance of air temperature and the advantages of radiant heating are briefly discussed, and a table is given showing the performance of black emitter radiant heating tunnels for a number of processes. Also J. Text Inst. 39 A. 434. 1948.

594. Hosken, J. C. Amer. Gas J., Apr. 1948, vol. 168, 25-26
FLEXIBLE GAS UNIT FOR INFRA-RED DRYING AND BAKING. The Potterton infra-red panel combines all the advantages of rapid production and extreme flexibility with great simplicity and the economy of gas. These panels consist of a special cast iron radiating surface heated from behind by a number of Bray burners placed in front of an insulating cover. Each panel has a gas rate of 10,000 B.T.U. and is about 23" x 12" x 4". They are designed to be quickly built up into banks or tunnels surrounding the work which can remain on the assembly line conveyor. The framework is made of steel angle or pipe and the walls are filled in with polished aluminium sheet which is an excellent reflector. Temperature control and details of the unit are described.

595. I.C.I. Ltd. A.C.B. Mathews B.P.568,153/1945.
HEATING APPARATUS. Apparatus for drying or stoving films of paint, varnish etc., consisting of a refractory diaphragm, at whose surface gas under pressure is burned, placed substantially at the focus of a parabolic chromium plated mirror, resulting in a parallel beam of radiant heat rays. The burner may be single. or there may be a multiplicity, or it may be in the form of a rod, and the mirror may be paraboloidal of a parabolic trough.

596. A. van den Linden Het Gas., Aug. 1947, 67, 157-163
USE OF GAS FOR INFRA RED HEATING. Infra red drying by electrical means was used on a large scale in America before the war for the stoving of paints and lacquers. The author in this paper is chiefly concerned in the application of gas heating to the same end: rapid drying in mass production. Most of the information is from English sources.

597. Macadam, A. C. F. Industr. Gas Times, 1948, vol. 11, 300, 302, 304, 306, 308, 310
GAS RADIANT HEAT APPLIANCES: ADVANTAGES. The application of radiant heating, with gas as the source of heat, for high-speed industrial drying, curing, and conditioning is discussed. Some of the successful drying processes carried out by infra-red, and the saving of time over previous drying methods, are summarised in a table. Black body emission at the temperature ranges 400°-850°F. and 1,100°-1,800°F. are tabulated. In the black emitter range, the standard types of dryers are the tunnel type and the flat panel type, and their construction is described. High intensity panels, chiefly used for annealing and ceramic firing, are usually of two types, the muffle furnace type with luminous refractory chamber, and the other with exposed flames and luminous refractory backing. Some types of luminous refractories used are briefly described. Certain practical performance figures of black emitter radiant heating tunnels are presented. See also Trans. Inst. Chem. Eng. 53 (11) 204-220, June 1948.

598. McGlaughlin, F. G. Textile World 1943 93 No.10 88
INFRA-RED GAS GENERATOR: DRYING EFFICIENCY. See under Textiles.

599. Mann C. P. Products Finishing Nov. 1944, 9, 28-42; Ceram. Abst. Amer. Ceram. Soc. 1945, 24, [illegible]
RADIANT GAS BURNERS IN THE MODERN OVEN. The application of the ceramic gas radiant burner to the drying of various finishes is discussed in detail. A diagram is given of the radial distribution of radiant heat in front of three typical incandescent ceramic-cup gas burners operating in open space. This indicates the spread of the heat from the burner. The application of this type of heat to the heating of strip is illustrated by two figures. Application of

the burners to material carried on a conveyor is shown. Advantages and disadvantages of this type of heating are as follows: Radiant heat sources can be readily located to provide uniform distribution over the whole area of the workpieces.

600. Pietermaat F. P. — Technische Wetenschappelijk Tijdschrift. 19(11),262-8,Nov. 1950
INFRA-RED HEATING. Description of versatile furnace. Illustr.

601. Progressive Silk Finishing Co. — Textile World 92(11),73,1942
RADIANT HEAT DRYING GENERATORS: APPLICATION. Carbomatic' gas fired radiant heat generators are described. Speeds increased by 33 to 50% and even to 100%. Any temperature between 125 and 250°F. can be had by adjusting burners. Separate units can be controlled, and the equiptment can be installed at any point, e.g. with tenter frames and Palmer machines.

602. Raber H. — Monatsbull. Schweiz. Gas. u. Wasserfachm., May 1948, vol. 28, 120-122
DRYING BY MEANS OF INFRA-RED RADIATION. Brief review of the work carried out by the Gas Light and Coke Company in this field, in which the advantages of gas-heated apparatus emitting very long waves (40,000 A and above) are emphasized.

603. Radiant Heating Ltd. — Ind. Heating Engnr. 1948 November 10.44.215
CONTINUOUS PRODUCTION OF COMPRESSED Strawboards. Includes a description of Ceramic Burner. Whole surface incandescent at 1600°F.

604. Ross J. O. Geschwind J. F. Ron Eng Corp — U.S.P. 2,391,195, 18.12.45 B.1.543, July 1949
INFRA-RED DRYER. Heating the air in contact, to not more than 10°F. above the temperature of the stock, prevents re-radiation.

605. Sanderson L. — Metallurgia, 1947, 35, 187-9, [illegible]-40; Chem. Abstr., 1947, 41, 3601
INFRA RED GAS BURNER. In an infrared gas burner, temperature is maintained by burning a mixture of air and gas on the radiating surface. The working temperature is in the region of 1200° at which the burner corresponds very closely to the perfect black-body radiator. This means that roughly 90% of the entire radiation from the burner will comprise effective infrared rays. One of the latest types of burners has a surface of refractory type, and by maintenance of an unobstructed orifice of the burner outlet this refractory is kept brilliantly radiant on the entire surface. The heat rays radiate at an angle of 45° from the burner, and focal or hot spots are avoided. A much lower fuel consumption is obtained in the modern infrared burner since no soot or other C

deposition occurs. A typical burner is described. It can be used for either high-or low-pressure gas, and by varying the dimensions of the burner heads capacities from 10,000 to 150,000 B.t.u. per hr. can be handled. Infrared gas heating is being applied to drying, melting, vaporizing, preheating, carburizing, singeing, annealing, charring, roasting, baking, and many other processes. Infrared burners should not be used at capacities less than 50% of the rated value, as efficiency will then be low.

606. Swatton D. Mass Production, Jan. 1947, 23, 48-53
INFRA-RED BY GAS. The principle employed in gas infra-red equipment is that of a black emitter, a black panel, instead of the lamps and reflectors of the electric system. The two types of unit, one a medium temperature unit giving a large surface area at about 650°F., the other a high temperature unit giving a smaller area of about 1600°F., are described as well as some gas infra-red tunnels, one of which is hexagonal for the convenient drying of long rectangular objects, corrugated sides for increased and more unidirectional radiation, and reverses the flue products to avoid high aero-motive effects, to increase the scrubbing effect and divert the flue products from the conveyor chain. Equipment for stoving a complete car body is discussed and the advantages of the gas-fired convection oven are compared with those of the infra-red tunnel.

607. Tesmer W. H. Gas Jan. 1945, 21, 27-8
INFRA-RED PAINT DRYING WITH GAS. The paper deals with the refractory type "infra-red" burner, and the results obtained with it in paint drying. The burner consists of a cup of porous alumina refractory with a thimble and a baffle in the centre. The gas is fed through the thimble, is deflected by the baffle and burns on the surface of the refractory giving a radiant glow, and no discernible flame. These burners give great flexibility in operation, and the product is of a high standard while fuel consumption is very low. The burner will operate on high or low pressure with hand or automatic control, and several may be assembled on one manifold making large ranges possible.

608. Workman P. Gas World, 12[illegible], Industr. Gas Suppl. [illegible], No. [illegible], 5, 1948
THE USE OF RADIANT TUBES IN THE INFRA-RED PROCESS. The author describes experiences with a prototype oven and states that the characteristic principles have changed little. During development a 1½ in. tube has been adopted as standard and the maximum practical length is 10 ft. when fitted with one injector. A burner which operates under an applied suction of 0.15 in. w.g., and air and gas flows of similar velocities, gives a long and luminous flame. The gas consumption is controlled not to exceed 20 cu. ft/hr/tube. A separate union control cock on each injector allows for

control of the intensity of radiation in different parts of the oven. Advantages of the multibar oven are flexibility in heat distribution in the vertical plane, low thermal capacity (quick heating up from cold), higher temperature head, increase in thermal efficiency and little maintenance; ovens can be designed to conform with the contour of the work. On some occasions, it is better for work to enter at the hotter end of the tunnel. A combination of radiant heat and forced convection can be advantageous and use can be made of the hot waste gases to obtain air movement within the oven. (5 figs.).

MILL-DRYING

609. MILL DRYING. See under Coal.

610. Agthe, F. T. Assr. to Allis - Chalmers U.S.P.2,398,989,23.4.46
AIR SWEPT BALL-MILL SYSTEM.

611. Combustion-Engr.-Superheater Inc. Chem.Eng.News.27(16) 1171
Raymond Pulverisor Division. 18/4/1949
1316, North Street, Chicago 22.
PULVERISING AND GRINDING TO FINE POWDER, WITH PNEUMATIC SEPARATION AND DRYING. Illustration.

612. Hanscomb, F. L. Mayer, J. Pulv.Fuel Conf.(Inst.Fuel).June 1947, 747-767
THE MILL UNIT AS HIGH-DUTY DRIER. Greater efficiency can be obtained and the cost of equipment reduced by drying and milling the coal in a single operation. The drying capacity of a mill is calculated and the combined mill performance is represented on a graph illustrating where the grinding capacity exceeds the drying capacity and vice versa. The paper concludes with an account of certain features of the mechanical design of the unit to which consideration must be given if operating troubles are to be avoided.

613. Helbig, A. B. Zement,vol.20,No.24,June 11,1931, pp. 564-566
DIE MAHLTROCKNUNG (DRYING IN GRINDING MILL). Calculations covering all processes of mill drying according to which dewatering of ground material takes place in mill.

614. [illegible], W. B. Amer.Inst.Min.Metall.Engrs.1945,Tech. Pub.1897,13pp; Min.Tech.9,No.5; Brit. Abstr.B.I.1945,370

FLASH-DRYING AND CALCINING AS DEVELOPED FROM MILL DRYING. All grinding plant using air removal has tended to dry the material being ground. This has now been developed to a process in which drying and/or calcining is the main object. High-speed hammer or squirrel-cage mills are used, with fan combined and a cyclone separator working on a closed air cycle. From this a venting fan draws off moist air, which is replaced by hot gases from a furnace. Very wet feed, containing 60% of H_2O, can be mised with pre-dried material before passing to the mill, whilst multi-stage working makes for thermal economy and high temperature, if required, in the final stage. Short heating periods and rapid cooling of hot gases make the process workable with heat-sensitive substances.

PACKAGING

615. —— C.R.D.5b.1947 Ministry of Supply, 10 pp.

THE USE OF DESICCANTS IN PACKAGING. General theory, reasons for use, quantity of desiccant required and formulae. A series of graphs showing the R.H./Water-content relationships for desiccants and wood.

616. —— Sci.Libr.Bibl.Series No.621,1943-45

THE WATER VAPOUR PERMEABILITY OF WRAPPING MATERIALS WITH SPECIAL REFERENCE TO THE FOOD INDUSTRY. 21 Refs.

617. —— Modern Packaging p.108,147,Aug.1949

FRUITS AND VEGETABLES.

618. —— Inst.fur Lebensmitteln Papier.1 167-73 1947 B.II.311 Aug.1948 (Long Abstract)

PHYSICAL PROPERTIES OF PACKAGING MATERIALS AT DIFFERENT AIR HUMIDITIES.

619. Brabender, G. J. Proc.1st Food Conf.,Inst.Food Tech., 1940,1,227.Chem.Abstr.,1941,35,2615

STUDIES ON WATER VAPOUR PERMEABILITY OF PAPER CONTAINERS FOR DRY FOODS. The Brabender technique (see Vol.13, No.[illegible]) for measuring water vapour permeability was used on 6 types of wrappers. It was found that the rate of permeability increased with rise in temperature. Increasing the relative humidity at constant temperature produced an increase in water vapour permeability.

The permeability of sorbing materials, e.g. glassine and regenerated cellulose, increased more rapidly with rise in relative humidity. Non-sorbing materials, e.g. cellulose acetate and rubber derivatives, showed a straight-line relationship between water vapour permeability and relative humidity at constant temperatures. The application of these studies to food packaging is discussed.

620. Carlin, G. T. et al. B.I.O.S.Misc.Rept.No.19 Pt2
pp. 394-5-6-7. Permeability to Water Vapour. Laboratory tests. Variations of ratios with temperature are included.
pp. 400 to 406. Lengthy description of permeability to water vapour (partly mathematical).
p. 406 - 10. Permeability to air and odorous substances.
411-430. Data concerning permeability.

621. Hicks, E. W. Mellor, J. D. J.Coun.Sci.Industr.Res. August.,1940. 13,278. Australia
NOTE ON THE RESISTANCE OF WRAPPING MATERIALS TO THE PASSAGE OF WATER VAPOUR. Discusses methods for determining the permeability of wrapping materials to water vapour. No convenient technique for use at freezing temperatures has been worked out. The efficiency of waxed and other treated papers is considered to depend more on imperfections of the coating than on permeability of the coating or impregnating material itself.

622. Coulter, S. T. Food Inds.18 352-5X Mar.1946
Jannen, R.
GAS PACKING OF DRY WHOLE MILK. Replacement of Oxygen by Vacuumising and filling head space with inert gas. Illustv.

623. Leach, W. G. Analyst,1941,66,241
THE MEASUREMENT OF THE WATER VAPOUR PERMEABILITY OF WRAPPING MATERIALS. Gives an illustrated description of apparatus suitable for determining the relative permeability to water vapour of various wrapping papers used for food materials.

PNEUMATIC DRYING

624. Anon Chem.Eng.g.57(6) p.110 June 1950
CONTINUOUS DRY CLASSIFIER. A new fluid bed unit by the Dorr Co. Dorrco Fluodry System. Hot air is blown upwards through the bed of lime stone where size separation in the 28-100 mesh range takes place, the finer material being carried over to cyclones. The whole process is preliminary to calcination.

625. ---- Br. Hydraulics R.A. Acc. No.367.
April 1950 D.S.I.R./3813/c
BIBLIOGRAPHY ON PNEUMATIC CONVEYING.

626. ---- Chem.Abstr.1948,42 5141
WATER SOFTENING PLANT. Sludge from lime-soda-ashplant, centrifuged, flash dried at 900°F, calcined at 1800°F (within 5 minutes) (for lime recovery.)

627. Anon Chem.Tr.J.,30 July 1948,vol.123,122
PNEUMATIC RING DRYER. A closed-circuit apparatus with continuous removal of product; the material is carried in a rapid stream of hot air or gases and remains in the drying duct for a period depending on its initial water content.

628. Anon. Internat.Chem.Eng. and Process Ind.29,10. 452-455. Oct.1948.
FLASH DRYING. This review includes grinding and drying. Two very good diagrams. For Corn gluten, products of combustion from coal-fired air heater enters the system at 1000 °F and a humidity of 0.01 lb H_2O vapour per lb. dry air. The air leaves the system at 200°F and 0.167 lb. humidity, The constant wet bulb is 146°F. and dew point 143°F. The partial pressure at 143°F. is 3.1193 and the v.pr. of water at 200°F is 11.526. The % RH in the exit gases is therefore 27.06%. The product temperature is 135°F. Coal, 3/8 inch. Filter cakes with dry return and disintegrater. Distillery Grains, Aluminium Sterate can be dried thus. For Heat sensitive materials 3 stage systems are used. Industrial Wastes and Sewage with incineration. Furfural waste as fertiliser. Ultra fine woodwaste. Coffe grounds. Br.Rema spray dryer illustrated. Air enters at 1000°F. and drops in 3 feet to 400°F.

629. ---- Amer.Inst.of Min.&Met.Engrs.Tech.Publ.1897 1945
REVIEW OF DEVELOPMENTS. No Data of a fundamental native is presented.

630. Barr, P. Industrial Chemist,25(294)362-5,July 1949
A NEW PNEUMATIC RING DRYER. C illustr. Descriptive, no data. Disintegrator is incorporated, therefore sieving of broken solids is not necessary. Coarse material re-passed through the mill. Automatic control, whereby the rate of feeding is adjusted so that the drying air is utilised to the same final outlet temperature.

631. Bar, P. J. B.P.593,379/1947
PROCESS AND APPARATUS FOR TREATING SOLID PARTICLES IN A DRYING GAS. Claim 1:- A process for drying solid materials in a drying gas using two circuits of airborne solid particles where-in wet particles are continuously introduced into an outer circuit, conveyed by a stream of hot gas through this circuit and into an inner circuit, dried particles being continuously withdrawn from the inner circuit and a stream of solid particles being peeled off from the inner circuit and returned to the outer circuit.

632. Barr, H. T. Louisiana State Univ.Bull 261.
TRIPLE PASS PNEUMATIC, CYLINDRICAL DRYER.

633. Berk, F. W. Ind.Chemist,p.85.Jan.1949
THE RING DRYER. Illustr. For powders, granular materials, crystals, and filter cakes, pneumatic principle. Accurate control of conditions and product. Can be combined with screenless grinding, so that filter cakes or crystals can be converted to powder in one operation.

633. Buttner-Werke Akt.-Ges. B.P.501,574 (March 1st,1939)
IMPROVEMENTS IN OR RELATING TO METHODS OF PNEUMATICALLY DRYING HEAT-SENSITIVE MATERIALS. In drying products such as beet leaves or lucerne by a stream of hot gases in vertical pipes, the gases enter at a temperature of about 800°C and leave at about 100°C. The rate of circulation of material is sufficient to cause the material separated for re-circulation to have a water content not exceeding 40% of the difference between initial and final water contents, so that the drying gas is rapidly cooled.

635. Collins, J. H. Bird, W. K. B.P.606,988,23.1.46.P.1.442. June 1949
DRYING AND COOLING OF GRANULAR MATERIALS. Wet, washed sand or fine coal is fed into the venturi section of a pipe line, and carried in suspension in hot air to a cyclone separator, provided at top with a venturi outlet for moisture and air, and at the bottom with a chamber in which the dried material is cooled by a stream of air induced by the venturi at the top.

636. Dietrich, L. Berlin Thesis 55 pp. 1941
Approx. dctn. of the temp. of particle surfaces and centres in uniflow suspension drying of brown coal by means of furnace gases.

637. Fison, J. and Chivers and Sons Ltd. B.P.568,170/1944
DRYING OF POWDERED OR MORE OR LESS FINELY DIVIDED MATERIAL. The material is introduced into a venturi through which passes a current of air. From there it is caused to flow several times through a drying path. This is formed by a upwardly extended zig-zag passage in which each limb is of such a length, that a vertical projection from its inlet end does not overlap at outlet, and is heated externally. A portion of the air issuing at the end of a drying cycle is caused to return to the drying path inlet.

638. Freiday, J. H. Paper Tr.Jul.128(17)p.22
Paper Mill, Comb.Eng.Co. N.Y. 28/4/1949
FLASH-DRYING OF BARK FOR BETTER BURNING. The "hogged" bark from logs is dried with 50% furnace gases from 65% M. to 45% M. Low exit gas temp., 400° F. Efficiency of furnaces and steam raising much increased.

639. Gordon, C. W. Pap. to Amer.Soc.Mech.Engrs,Dec.1947; abstr. in Chem.Age,13 Dec.1947,vol.57, 756; and in J.Sci. Industr.Res.,India, Feb.1948,vol.7,94; and Mech.Engng, Apr.1948,vol.70.356-357

FLASH DRYING. This new system which has resulted in large savings in industry through more economical processing and recovery of waste materials, employs the general principle of drying by vapourization into air. The equipment permits the product to be delivered at a specific moisture content in particle form ranging in size from fine to granular. It is simple in design and operation and consists of a heater, wet feeder, mixer, agitation and collection systems, dry divider, cooling and transport systems, and instruments and controls. Because of the rapidity of operation, only a few lb. of material are in it at any one time. The drying takes place when the material is conducted into a turbulent stream of hot air with temperatures ranging up to 1300°F. Chemicals, food products and sewage sludge, fines from coal mine washeries, spent grain from breweries and distilleries, and a large number of waste products from chemical and process plants, can be dried by this method. The excess heat may be profitably used for steam generation.

640. Gordon, C. W. Chem.Eng.Progr.45 8.477-481 Aug.49
Combust.Eng.Co.Inc. Chicago

FLASH DRYING. A general account of the processing of various materials with simple relevant data, for Sewage Sludge. Distillery and Corn Products, Clay and Coal. Grinding and Cage Mills. Full diagrams of Dryers Raymond Flash Drying System for Coal and also with Cage Mill and with Calcining System.

Tables. 1 Evaporative capacity of various sizes of Flash Drying systems, 36 lb. to 35,800 lb. H_2O/hour.
2 Operating Costs v.s. Capacity system for Fine Coal. Discussion.

Applications to furfural wastes, fine wood waste, flotation fines. Eliminates dumping of wastes into streams.

641. Greene, J. W. and
Rohrmann, F. A.

PNEUMATIC DRYING. See under Potato for fundamental data.

642. Haas, H. West,Gas.,7,34,72,74,(1931) Sept.

DESIGNING A "VENTURI" DIRECT-FIRED AIR DRYER. Notes on air-heater designed by Haas.

643. Hariu, O. H. Molstad, M. C. Ind.Eng.Chem.41 1148-60,1949 Chem. Abstr.43(17) 6476,10.9.1949

PRESSURE DROP IN VERTICAL TUBES IN TRANSPORT OF SOLIDS BY GASES. Sand and catalyst particles were used for experiments in glass tubes. A solids and a gas pressure drop are indicated.

Herbert, A. Ltd.   B.P.619,352,4.12.46
Mahler, J. H.
APPARATUS FOR DRYING GROUND MATERIAL. Inorg. material from a grinder passes into a stream of hot dry air, from which it is separated by a cyclone. The moisture content of 300-mesh material is reduced to 0.1%.

645. Hottel, H. C. Kalitinsky, A.   Instruments 17 40-42 1944
HIGH VELOCITY AIR STREAM: TEMPERATURE MEASUREMENT. The merits of the various kinds of probes are discussed and tests made thereon. The Pratt and Whitney high velocity stagnation temperature probe was found to be satisfactory for precision measurements. Results of experiments indicate that bare wire thermocouples can be used for the great majority of measurements at velocities below 300 ft/sec.

646. Korn, A. H.   Chem. Engg. 57(3)108-11 March 1950
HOW SOLIDS FLOW IN PNEUMATIC HANDLING SYSTEMS. Dissatisfied with empirical design methods, at present needed for pneumatic handling, the author has taken a long step toward uncovering a rational approach. Mathematical approach and diagrams.

647. Lyakovskii, D. N.   Kotloturbostroenie 1947(5) [illegible]-31
HEAT EXCHANGE BY CONVECTION BETWEEN SUSPENDED SPHERICAL PARTICLES AND THE SURROUNDING MEDIUM. Graphs and formulae for calculations of heat emission of suspended particles by convection were obtained by Nusselt at low Reynolds number; his limiting law for heat emission of dust particles is not universal.   D.S.I.R. [illegible]

648. Fahrson, I. M. and R. V.   B.P.605,478 16.11.45 Swed. [illegible]
Abstr.B.III 91 Feb.1949
DRYING OF VEGETABLE OR OTHER MATTER. Heterogeneous particle sizes introduced obliquely downward into an upward air blast, adjustable by dampers. Heavier particles are beaten upwards again by paddle blades until dry and light enough to pass upward with the smaller particles.

649. Rammler, E. et al   Feuerungstech. 1938. 26. 241-53
DRYING AND THERMAL TESTS WITH A SUSPENSION DRYER. A detailed illustrated report is given of an investigation of the working processes and the economics of drying plant used in the preparation of fodder for substances containing albumen, but which may also be adapted for drying coal. The essential feature is that the material is dried while held in suspension or being transported by hot gases.

650. Rammler, E. and   Braunkohle, 1939, 38, 1-10, 18-26
Augustin, O.
VELOCITY OF COAL PARTICLES IN SUSPENSION. CONTRIBUTION TO THE STUDY OF PROCESSES IN DRYERS IN WHICH THE MATERIAL IS AIR-BORNE. The authors discuss the theory of dryers in which the material to be dried is suspended as particles in air currents and present calculations and examples which facilitate the determination of appropriate transverse dimensions of such dryers. The determination of the length of the drying path presents more difficulty and will form the subject of a later work.

651. Reavell, B. N.
PNEUMATIC DRYING COSTS. See under Coal.

652. Reavell, B. N. Pulv. Fuel Conf., Inst. Fuel, June 1947, 567-577
DRYING OF FINE COAL IN THE THERMO-VENTURI DRIER. After showing that none of the existing industrial driers (tunnel, spray and rotary driers) are suitable for fine coal drying, because of their comparatively low thermal efficiency and the large surface of the material exposed to air, the author traces the development of the pneumatic drier, culminating in the thermo-venturi type. The paper concludes with a brief account of the regulation of the plant and safety devices, and an estimation of the drying cost.

653. Rongsted, W. C. Gottfried, J. B. Industr. Engng. Chem., 1941, 33, 1544
Swallen, L. C.
DRYING HEAT-SENSITIVE SUBSTANCES. A MODIFIED FISH-DRYING SYSTEM. Describes a process for drying substances such as zein which are sensitive to heat. The Raymond flash-drying system combines drying and grinding in a single operation. Details of the drying process are given

654. Scott, A. W. Fuel and the Future 1, 271. 1948
APPLICATIONS OF PNEUMATIC DRYING. Fish meal, beet leaves, lucerne 100 such dryers in Germany up to 3 tons per hour. 25 K.W. power used per ton evaporation.

655. Smith, A. R. Combustion, 11(5)25-29 Nov. 1939
FLASH DRYING EXTENDS LIMITS OF PRIOR PRACTICE. Description, diagrams and illustrations of the "new art" of flash drying. Chiefly relating to the inclusion of moist material in the burning to regulate the temperature. Teachings:-

1. Gases of high temperature may be used, 800-1400 °F.
2. Materials of high ash content and low heat value may be successfully burned with suitable modifications.
3. Recirculation of dried material may be practiced.
4. The moisture content of the fuel is several times greater than thought possible.
5. Fuels of low heat value respond if heat deficiency is made up with, say, oil to start the cycle.
6. Heat treatment of gases may be provided.

656. Sturgeon, R. A. B.P. 501,129 February 22nd, 1939
IMPROVEMENTS IN DRYING APPARATUS. Vegetable crops in finely divided form or granular or fibrous materials are dried while carried in a stream of hot air in a vertical chamber, the lower sides of which diverge at an angle of 14° to give a decreasing gas velocity.

657. Tornes, Eilif D.S.I.R. Transl. from Norwegian, of a visit to U.S.A. April, 1949
To many American fish handling plant. The pneumatic dryer was considered to give a much better product than the steam tube or fire tube dryers. The temperature of inlet air was 250°-350°F. and output 10 tons/hour.

658. Vogt, E. G. White, R. R. Ind. Eng. Chem. 40 1731-8 1948
Experimented on the flow of suspensions of sand, steel shot, clover seed, and wheat through a 0.5 inch pipe. An equation for pressure drop was developed on the basis of the data obtained and checked against literature data on the conveyance of wheat in pipes 2 to 16 inches diameter.

ROTARY DRYING

659.
ROTARY DRYERS see under Coal.

660. Anon. Ind.Chemist 3,554 . 1927
ROTARY DRYER. Calculations of air quantities, humidities, efficiency, and length of rotary dryers.

661. Anon. Chem.Fabrik 4, 434-5, 1931,Nov.4,Chem. Ztg,56,188,1932.5 March
SEYFFERT RAPID FORCED DRAFT DRYER.

662. Anon. Chem.Fabriksuppl.7,19-20,1934,Jan.10
SEYFFERT DRYER: The dryer consists of a rotating cylinder, the inside of which, is fitted with a multitude of baffles (themsixated) for continuous expose of undried material to the hot gas stream passing through the cylinder.

663. Anon. Demag News v 6 1 Feb.1932 p.1-6
GIANT DEMAG DRUM DRIER FOR BEET SHREDS. Demag. recently, completed erection of drum drier for shredded beet-root supplied to sugar refinery at Bruehl; capable of dealing with 60 tons of beet shreds in 24 hr. plant is remarkable for its size and excellent economic efficiency; diameter of new drum installed by Demag is 10.5 ft. and length 60 ft.

664. Anon. Rock Products,vol.34,no.9.Apr.25,1931, pp.41-43,6 figs.
SAND DRY PLANT UNDER AUTOMATIC CONTROL. Description of rotary drier of special design with automatic oil-burning equipment used by Sand Products Corp., Milwaukee, Wis.; system can be applied to driers for stone, gypsum, cement, raw materials, etc.

665. Anon. Chem.Engg.54.150.Oct.1947
MULTI LOUVRE DRYER.

666. Anon. Iron & Coal Tr.Review.152 1025.7-6.1946
APPLICATION OF ROTARY LOUVRE DRIERS. see under Coal.

667. ---- Edgar Allen News 28 no(326).349-53 D.S.I.R.Library
ROTARY DRUM DRYERS including Turbo-dryers, 4 Types of Rotary Dryer. Design Characteristics. Main features are described.

668. Anon. Industr.Chemist.25 No.295 p.391 Aug.1949

CONTINUOUS ROTARY EVAPORATOR. Found satisfactory for evaporating solvents from vegetable oils and for those containing finely divided solids. Diagrams and Illustrations.

669. Anon. Internat.Chem.Engg.29 (11) p.516-519. Nov.1948

ROTARY DRUM DRYERS. A general description of the various kinds of rotary dryers, with illustrations and diagrams. Turbo-dryers are illustrated, instancing starch dried from 40% to 20%. M. at 1.5 lb. steam per lb. of water evaporated. Recirculation of air and low speed output prevents loss of dust. No data.

670. Anon. Chem.App.18 79-80,1931,April 10

A NEW ABBREVIATED ROTARY DRYER. STUNBRUCKNER SYSTEM.

671. Anon. Revue de l' industrie Minerale n 356 Oct.15 1935 p.387-8; see also brief English abstract in Colliery Eng v 13 n 143 Jan.1936 p.32

UN NOVEAU SECHOIR POUR MATIERES GRANULEUSES ET PULVERULENTES. Illustrated description of contact drier for granular and pulverized materials, developed in Germany, in which hot gases from furnace are drawn by fan through stationary drum containing rotating shaft on which mounted concentric rings of angle iron, or perforated or slotted disks for muddy materials; apparatus is thermally more effective than tumbler barrel and forms little or no dust.

672. Anon. Mech Handling v 24 n 4 Apr.1937 p p.109-111

BUELL-BUETTNER" ROTARY DRIERS. Design features of gas drier for materials with arrangement of internal shelving and operating either on uniflow or counterflow principle.

673. Anon. Food Inds.9 Jan.1937

ROTARY DRYERS FOR FOODS. Rotary dryer by Link Belt Co. Air penetrates the material through air chambers lining the inside of the drum.

674. Anselm, W. Radix Rundschau 3-61.1950

ROTARY KILNS. Transmission of heat.

675. C.O. Bartlett-Snow Co. Bulletin No.89 55 pp.1948 Ind.Eng.Chem.
Cleveland, Ohio. 40 (8) 35,1948
ROTARY DRYERS. COOLERS. CALCINERS KILNS AND ASSOCIATED EQUIPMENT. A well illustrated and explanatory brochure. 9 pages of technical data on steam, specific heats, apparent densities of industrial materials, water vapour pressures and calculations, humidity chart.

676. Bayard, R. A. Chem.Met.Eng.,Mar.1945,52,100-2)
FLOW OF MATERIAL THROUGH A ROTARY KILN. Three nomographs show respectively the rate of passage of a charge through an inclined kiln, the sectional area of the charge, and the height of the charge.

677. Bill, C. E. Ind.Eng.Chem.1938 30 997-9
Louisville Drying Machine Co.
ROTARY STEAM TUBE DRYER. A brief description of a rotary dryer fitted with 2 concentric circles of stationary steam tubes. Material such as fish offal, distillers waste, fruit and vegetable pulps, are tumbled among the steam tubes, heated in a humid atmosphere at comparatively low temperature, and the moisture carried away by an air counter current. Case hardening is avoided. Filter cakes, clays, chalk, and heavy chemicals can be dried in this way. Exhaust steam can be used. Capacity varied by steam pressure. No data.

678/9 Buell Combustion Co. Ltd. B.P.553,425/1943
DRYING APPARATUS FOR GRANULAR MATERIALS. An apparatus for drying granular materials by means of heated gas in a rotary drying chamber in which one or more centrifugal dust separators are built into the collecting casing or hood into which the dried material and hot gases are delivered from the outlet of the drying chamber in such a way that the hot gases pass directly into the inlet of the separator or separators without leaving the collecting casing.

680. Dunford and Elliot Chemical Age.29 467-8, 18 Nov.1933
A ROTARY DRYER WITH UNLIMITED APPLICATIONS.

681. Dunford and Elliott (Sheffield) Ltd., Techniview 5 Feb.1950
44 Victoria St.
RADIANT HEAT ROTARY LOUVRE DRYER. Gas fired radiant panels at centre for max.Temps. of 450° 850° and 1,100°C.

682. Eimco Corporation Chem.Ind.Oct.1948,63,4,647
CONTINUOUS ROTARY DRYER. Advertisments and Illustrations. For crystalline products, etc., which dewater rapidly. Monel metal or stainless steel. Fully automatic and continuous.

683. Erisman, J. L. Ind.Eng.Chem. 1938 30,996-7
Link Belt Co., Chicago
ROTO-LOUVRE DRYER. A brief illustrated description of the dryer with performance data for 9 materials including casein and apple pomace, cheese.

684. Fisher, E. H. Am.Gas.Jl., vol. 134 no. 5, May 1931, pp.39-40, 7 figs.
NATURAL GAS AIDS IN SAND PRODUCTION. Practice of Silica Co. of California, Ltd., in Contra Costa County; natural gas used to fire rotary type drier used to remove moisture after sand has been taken from grader; natural gas fuel is also used for steam shovel.

685. Friedman, S. J. Chem.Eng.Progress. 45 (8) 482-493,
Marshall, W. R. Aug.1949
STUDIES IN ROTARY DRYING PT.I. HOLD UP AND DUSTING. In the design and operation of rotary dryers, the amount of material retained in the dryer influences the heat transfer occurring in the equipment and the lower required to drive it, whereas the dusting from the dryer limits the amount of air which can be economically employed. This paper analyzes the factors which influence the hold-up and dusting in rotary dryers, reviews existing date, and presents results of an investigation in which the hold-up and dusting in a 1 ft. diameter by 6 ft. long rotary dryer were measured for eleven different materials. Over a wide range of dryer slope, rate of rotation, feed rate, air rate, and material characteristics, it was found that the hold-up in a rotary dryer, for both counter and cocurrent air flow, can be estimated satisfactorily from equations that are presented. These equations also correlate the data of other investigators and satisfactorily predict hold-up in large dryers. Although no quantitive correlation was obtained, the effects of rate of rotation, slope, feed rate, and air rate on dust losses from the small rotary dryer are presented. The hold-up varied directly as feed rate and inversely as slope and speed.

686. Friedman, S. J. Chem.Eng.Progress. 45 (9) 573-589,
Marshall, W. R. Sept.1949
STUDIES IN ROTARY DRYING. PT.II. HEAT AND MASS TRANSFER. The effect of air rate, feed rate, rate of rotation, slope, and number of flights on the heat transfer occurring from hot air to several different sands was studied in a 1 ft. by 6 ft. rotary dryer. Material temperatures and heat losses were measured along the dryer length and columetric heat-transfer coefficients were evaluated over six incremental lengths of the dryer. The effect of the variables listed on the rate of heat transfer are presented for both counter- and co-current air flow. Tests were also conducted in

which sand was dried in the experimental unit. Material temperatures and moisture contents were measured along the dryer length, permitting the evaluation of a true average temperature difference. It was found that the magnitude of the heat-transfer coefficients and the effects of the operating variables in the drying tests were the same as those obtained in the heat-transfer tests. A method of scale-up is suggested.

687. Gilbert, W. S. Engineer 150, 1930. 6 papers. pp. 500, 530, 574, 587, 617, 640

THE HEATING AND DRYING OF GRANULAR MATERIALS BY CONVECTION.
Experimental work carried out at the expense of Edgar Allen & Co., Sheffield, Author had noticed a very slow rate of heat-transfer in rotary dryers for coal and in rotary coalers for cement clinker. Exit gases could not be reduced below 800°F in a wet process. Little or nothing in technical books or papers indicating rate of heat-transfer from hot gases to granular solids.
Considered that information was desired on:-
(a) Effect of Air V., air T., and dimensions of lumps immersed in a current of hot air.
(b) For layers, effect of variations of Air T., Air V. Thickness of layer and dimensions of lumps.
(c) In each case B.T.U. transfer per sq. ft. of surface per hour per degree would be required, the temperature difference being that between the average surface temperature of the lump and the air temperature.

No. 1. The apparatus used, and method.
2. Results with Coal and 15 curves of results.
3. Clay Drying. 7 curves of results.
4. Coal Drying in thick layers.
5. Application of Mathematical theory of Heat Conduction to Drying Problems.
6. Calcs. relating to thick layer dryers with continuous feed, e.g. to rotary dryers.

Conclusion. Rate of Heat-Transfer in a rotary kiln is slow, because heat is supplied only to the outer surfaces of the charge and and not to the surface of each particle. There are practical difficulties in exposing fully each particle to the action of the hot-gases for say, 40% of the time, but since the advantage of doing so is now understood, perhaps design of rotary kilns will be improved.

688. Gutzeit, G. Amer. Soc. Mech. Engrs. Meeting Apr. 1950
Spraul, J. R.
ROTARY DRYERS. Suggestions are made for the construction of rotary dryers and test data are presented for the drying of various materials.

689. Guye, F. Radix Rundschau 172-176.1949
ROTARY KILNS. Methods of calculating heat losses.

690. Harrigan, H.W., Royd, J.A. Chem.Met Eng.g.46 214-17 1939
FACTORS IN CHOOSING A ROTARY DRYER

691. Horgan, J. T. Trans.Inst.Chem.Engrs.6 p.131-144
Conf.6/12/1928
ROTARY DRYERS. A general account, including performance and data curves, for Coal and Clay cubes. Diagrams and illustrations very clearly set out.

692. Jaspers, M. J. M. Rev.Materiaux Constr.Trav.Publ.Ed.C.
No.410.373-378 and No. 411.421-5.
ROTARY KILNS. Includes heat distribution in the combustion zones, and transmission of heat from the gases to the solid materials.

693. Khodorov, E. I. Tsement 1944,10,No.4,14-18; Chem.Abst.
1945,39,598.
REGULATING THE HEAT OF ROTARY KILNS. The temperature within a rotary kiln can be controlled by regulating the fuel and air supply and the temperature of the flue gases. Formulae are given connecting the factors having direct bearing on the heat requirements and the temperature, such as moisture content of the slurry, calorific value of the fuel, kiln output, and compn. of flue gases. A nomogram connects the coal consumption with the compn. of the flue gases, and another connects the excess air and the compn. of the flue gases.

694. Van Krevelen, D. W. Chem.Weekbl.,1949,45,290-295
DRYING OF GRANULATED FERTILISERS IN DRUM DRYERS. The mechanism of drying granulated fertilisers is discussed. The capacity of the dryers (kg. of H_2O per cu.m. of dryer vol. per hr.) is 50 times as small for these materials as for powdered coal. Rate of drying increases rapidly with temperature and its grain diameter. It is independent of gas velocity.

695. Van Krevelen, D. W. J.S.C.I.68(2)59-66 Feb.1949
Hoftijzer, P. J. Netherlands
State Mines.Chem.Lab.
Geleen, Holland.
DRYING OF GRANULATED MATERIALS I. DRYING OF A SINGLE GRANULE. Investigation into the drying of a granule of porous material in a current of air . Purpose to work out a method for prediction of dimensions of apparatus from the drying characteristics of the material

696. Van Krevelen, D. W. J.Soc.chem.Ind.,Lond.,1949,68,91-97.
Hoftijzer, P. T.
DRYING OF GRANULATED MATERIALS. II. DRYING OF GRANULES IN ROTARY DRYERS. The product of residence time, r.p.m., ratio of diameter to length of dryer, and the tangent of the angle of inclination is approximately const. for every dryer. The val. of this const. depends on the construction of the dryer and varies nearly inversely as the number of "steps" into which the diameter of the dryer is divided by the lifter construction. The drying rate of granules which contain no sol. salts in a rotary dryer is lower than that in a freely-suspended state at the same Reynolds number of flow. The ratio (q) of the drying rate in a rotary dryer to that of freely-suspended granules increases with the number of revolutions (n) of the dryer. Experiments in a laboratory dryer show that q is approximately 0.20 - 0.25 when n = 10 r.p.m. and q n.$^{0.5}$, but no quant. data were obtainable for the drying rate in the second period. The rate of drying of nitro-chalk (fertiliser) granules (average grain size 0.2-0.3 cm.) in a commercial rotary dryer (2.6 m. in internal diameter and 12 m. in length) is the same as for freely-suspended granules at the same temperature. Drying rate is independent of air velocity and charge of material, but is influenced by granule diameter, twmp., and time of residence.

697. Krupp, Essen FIAT.Microfilm Reel.L.51.Frames 5792-5800 E U.S.Dept.Commerce.Off.Tech. Service.P.B.L.74,625 Apr.1939

698. Link Belt Co. B.P.613,176 14.6.46 B.I.442 June 1949
ROTARY DRYER OR COOLER. The dryer has a number of circumferential compartments along the axis. Filler bars ensure even distribution of of drying fluid.

699. Marshall Gas World 126 3268 Coking Sect.40-3.1947
DATA ON HORIZONTAL ROTARY DRYER.

700. Matouschek, F. Rev.Materiaux Constr.Trav.Pub.Ed.C.No.401 43-46.1949

ROTARY KILNS. Methods of calculating heat losses.

701. Mertz Ind.Eng.Chem.1921 13 449
DIRECT HEAT, ROTARY DRYING APPARATUS

702. Miller, C.O. Smith, B.A. Amer Inst.Chem.Eng.Trans.38 841-864 1942
Schuette, W.H. Case School,
of applied Science
Cleveland, Ohio.
FACTORS INFLUENCING THE OPERATION OF ROTARY DRYERS. II. THE ROTARY DRYER AS A HEAT EXCHANGER. Classification according to design. Analysis of the Heat Transfer Problem quoting equation by Walker,

Lewis, McAdams and Gilliland, Application to Rotary Dryers. 7 Curves shewing conditions of air in dryer and moisture temperature gradients. Experimental Procedure, Data, and Discussion. Effect of Temperature Difference. Mathematical Analysis and Summary.

703. Nordberg, B. Rock Prod., Aug. 1946, 49, 98-103, 119; Battelle Libr. Rev., Nov. 1946, No. 11, 22

MARQUETTE'S 475ft. ROTARY KILN. The operation of the kiln and its performance are discussed, along with a description of the kiln and its related operating equipment and control devices. It was designed for maximum fuel efficiency using low grade Iowa coal. Instrumentation, which it very complete, is described.

704. Peters. Chem. Zig. 57, 643-4 (1933)

NEW ROTARY KILN. Flame does not come in contact with material directly. Made by Buetner Werke.

705. Pickering, R.W. Feakes, F. Jnl. Appl. Chem. 1 (1) 13-19. Jan. 1951
Fitzgerald, M.L.
Univ. of W. Australia

TIME FOR PASSAGE OF MATERIAL THROUGH ROTARY KILNS. An expression is derived relating time of passage to slope, length, diameter, rate of rotation, feed rate and rill angle of the material. The expression is in accordance with previously published empirical relations. Application to kiln or dryer control and design is illustrated by an example.

706. Prutton, C.F. Miller, C.O. Amer. Inst. Chem. Engrs. Trans. 38 123-141
Schutte, W.H. 1942. Written discussion pp. 251-7

FACTORS INFLUENCING THE PERFORMANCE OF ROTARY DRYERS. I. Analysis of Rotary Dryer Problem. Experimental Equipment and Method, Flight Design and Loading, using Photographic technique (10 photographs). Effect of variables on time of passage:-

Feed Rate or % loading.
No. of flights.
Design of flights.
Slope of cylinder
Rate of Rotation
Length and diameter.
Physical Properties of the charge.
Air Velocity.

707. Schmid. Zement 23, 57-8 (1934) Feb. 1.

IMPROVING THE HEAT ECONOMY OF THE WET PROCESS ROTARY KILN. Description of the improvements introduced by the combined Krupp-Guesanwerk and Andrea systems using special internal fixtures and chains in a rotary kiln. Some details are given showing the reduction in temperature of the exit gases by the use of these internal arrangements.

708. Schwieter — Archiv fuer Waermewirtschaft, 12, No. 12, Dec. 1931, pp. 353-355, 2 figs

TROMMELTROCKNER MIT WANDERROSTFEUERUNG (DRUM DRIERS FOR SUGAR--BEET COSETTES WITH TRAVELLING-GRATE STOKERS. Investigation of draft, secondary air admission, temperatures of charge and gases, and yield of dried product; rules for design and operation of plants.

709. Schnacky, J. F. — Chem. Engng, 1948, 55, (5), 143-144; abstr. in Chem. Abstr., 1948, 42, 6587

SIMPLIFIED METHOD OF FIGURING ROTARY DRYER PERFORMANCE. Knowledge of moisture content of material as function of temperature allows preparation of plot of heat required vs length of dryer, from which dryer requirements can be estimated.

710. Smith, B. A. of Bartlett Snow Corp. — Ind. Eng. Chem. Symposium 30 993-5 1938.

ROTARY DRYERS. Classification of Rotary dryers. Description of Heat Transfer Mechanism in which data are given on moisture, removal and thermal efficiency. A 1949 brochure is available.

711. Spooner, W. W. — B.P. 609,566 16.3.46 B.III 137 March 1949

ROTARY DRYING CYLINDERS. Increased Efficiency is obtained by means of fans or impellers arranged on a shaft mounted eccentrically to axis of rotation of the cylinder directing streams of the gas or steam on to the internal surface of the cylinder.

712. Sullivan, J.D. Maier, C.G. Rolston, O.C. — U.S. Bureau of Mines Techn. Paper 384. 1927.

A study of the factors that influence the rate of progress of crushed materials through a Kiln which contains no lifting flights, and hence is not subject to the same operating variables as a rotary dryer.

713. Akticbolaget Svenska Flak fabriken — B.P. 550,810 1943

IMPROVEMENTS IN ROTARY DRUMS. The drying medium is passed through the laminated wall, the laminae being designed to prevent material escaping.

714. Tyler, G. B. — U.S. PAT., 2,339,207 11/1/44.

DRYING APPARATUS FOR GRANULAR MATERIAL. A rotary dryer is described.

715. Vahl. L. — Chem. Weekbl., 1949, 45, 325-333

TRANSPORT (OF MATERIALS) THROUGH CONTINUOUS DRUM DRYERS. The factors which promote the transport of material i.e., slope of the drum, forward movement of the material by the agency of the drying air, and the differences in level of the freely-moving material at the inlet and outlet, in a horizontal dryer, have been investigated. A knowledge of these factors is essential to ensure uniformity in the running and stopping period, when material of various grists is being dried, and to determine the correct load for max. drying capacity per cu. m. of dryer vol.

716. Vance, J. L. Am. Gas J. 136, No. 3 29-30 (1932) Mar.
GAS-FIRED ROTARY DRYERS. Features of rotary kiln dryer, manufactured in So. California and used for dehydrating wide range of substances for market.

717. Waddams, A. I. Internat. Chem. Eng. 31 (10) 452 1950 Oct.
DRYING. Mainly reviewing the work of Friedman and Marshall 1949, and van Krevelin 1949.

SPRAY DRYING

General Process

718. Anon. Chem. Inds. 63 (4) 599. Oct. 48
Where solid product has a low m.p. it has been found feasible to provide an outer manifold through which cold air is introduced. In this way, particles may be cooled while still suspended.

719. ---- B.I.O.S. Report 999
SPRAY DRYING OF P.V.C. EMULSIONS.

720. Anon. Chem. Trade J. 89, 158 (1931)
The Ravo-Rapid spray-drying system is briefly described.

721. Anon. Chem. Ind. 9/1948 63.3.p.402
Freeze drying specified in the first U.S. Plants, but the Danes and Swedes use Spray drying for Blood and have recently used it for Penicillin.

722. ---- Chem. Age 26 419 May 7 1932
OUTLINE OF PATENTS TO DATE

723. ---- Bowen Engg. U.S.A.
Spray Dryer. Complete instructions for fully Automatic Control. Flexibility. 5-10 tons/day.

724. Editorial Food Inds. 1929 1 (10) 343-4
Applications - Vegetable pulps.
Possibilities - Waste products, e.g. blood, whey, low grade milk.

725. Alford, E. C. Chem. & Met. Eng. 41 No. 12 Dec. 1934 p. 634-6
SPRAY DRYING INSECTICIDES AND ALLIED CHEMICALS. Features of equipment and practice at plant of Westwell Chemical Co. at Whittier, California.

726. Antoni, A. Chem.Eng.Congr.World Power Conf.1936
Adv.Proof C.19
DRYING BY SPRAY OR ATOMISATION. Mechanism and Laws. 2 methods, High pressure jet and centrifugal force. Applications in food industry.

727. Antoni, A. Technique Moderne 27 No.22 Nov.15 1935
p.739-44
LE SECHAGE PAR ATOMISATION. Drying by atomization; principles of various processes; details of equipment used.

728. Antoni, A. Genie Civil 110 No.2856 and 2857 May 8
1937 p.417-20 and May 15 p.433-7
LE SECHAGE PAR PULVERISATION. May 8: Theory of drying by atomization: mechanism of process and factors affecting physical properties and appearance of dried products. May 15: Atomization by compressed air and by centrifuging; features of Grey-Jensen, Nubilosa, and Kestner atomizing driers; apparatus for preliminary concentration of material to be dried.

729. Barkholt, H. Dechema Monograph 4, 97-109.1931
Spray Drying. Separation of Solid and Liquid Substances by Spray drying.

730. Barkholt, H. Chem.Fabrik.4, 258, 1931
The Separation of Solid materials from Liquids by spray drying and crystallization. (Barkholt gave a paper at Vienna).

731. Bergolitz Farmatsiya 1945 8 3 15-18
Spray dried thermolabile concentrates gave better quality and higher stability than when vacuum dried.

732. Bowen, W. S. Bowen Res. Corp. Ind.Eng.Chem.1938 30(9)1001-2
Garwood N.J.
SPRAY DRYING. A diagrammatic illustration of the spray drying process using a centrifugal atomiser and homogenising atomisers. Phosphates, sodium sulphate, colloidal solutions such as milk, blood, black liquor, sludges, slurries, soap, (soap powder is spray chilled).

733. Coslett, T. A. Jnl.Imp.Coll.5 68-79 1949
SOME SPRAY DRYING PROBLEMS. The effects of separate variables and factors affecting spray drying are discussed and the problems concerning each are indicated. A chart illustrates the effects of 7 variables on product moisture, bulk density, particle size, charring and exhaust air temperature. 12 Refs. At present there is no method of predicting accurately the performance of a nozzle under specified conditions of pressure, viscosity etc.

734. D'Ans, P. Chem.Apparatus,1941,28,49.Chem.Abstr., 1941,35,6839.
SPRAY-DRYING AND ITS PLACE IN INDUSTRY. (transl. title). Characteristics of different types of spray-drying equipment are described and their advantages and disadvantages are explained.

735. Van Deest, S. Heat.Pipg. and Air Conditg. 15 440 1943
THE SPRAY METHOD: LIQUID DRYING. Discusses the theory and practice of spray drying liquid foods such as eggs, milk, etc.

736. Edeling, C. Milchwissenchaft. 1 and 2 88-95 1947
THE THEORY AND PRACTICE OF SPRAY DRYING AND ITS APPLICATION TO THE MILK INDUSTRY.

737. Farmer, E.H. Six, C.G. Fuel and the Future 1948 pp. 277-287
SPRAY AND ROLLER DRYING. Types of Drum Dryers. Relation between steam pressure, Film thickness, and speed of drum. Uniformity of film thickness. Air Venting and Condensate removal. Efficiency and Fuel Economy. Vacuum Drum Dryers. A general description of Spray drying and methods of supplying hot gases. Types of atomisers, recovery of dried products. Curves shewing relations between the vol. temperature and humidity of air and between thermal efficiencies and humidities of exit air. Drum Dryer takes 1¼lb. steam and spray 2 to 5 lb. steam for 1 lb. of water evaporated.

738. Fleming Ind.Eng.Chem. 1921 13 447
THE SPRAY DRYING PROCESS

739 Fogler, H. H. T.A.P.P.I. 32 9 389-393. 1949
SPRAY DRYING HEAT TRANSFER COEFFICIENTS FOR SULPHITE WASTE LIQUOR. Sulphite liquors at concentrations from 8 to 45% were dried with flue gas at temperatures ranging from 300°F to 600°F. From the data obtained, heat transfer coefficients were calculated. _ These ranged from 4 to 10 B.T.U. per hour, per c.ft. of dryer volume, per degree F.

740. Gerhold, C.G. Mekler, L.A. U.S.2,467,470 19.4.1949
Univ.Oil Prod.Co.
DRYING AND SPRAYING APPARATUS FOR FORMING SPHERICAL PARTICLES USED IN HYDROCARBON REACTIONS. In the described app., a sol. or hydrated oxide is passed on to an atomising disc and formed into draplets, while a drying gas stream directed upon the drops travels in the same direction and speed so that little motion is created between gas stream and draplets.

741. de Haas, T. K. Chem.Weekbl., 1949, 45, 330-333
STEAM-DRUM AND SPRAY DRYERS. The physical factors in drying are discussed for both types, including the use of rotating-disc and nozzle atomizers.

742. Ju Chin Chu. Stout, L.E. Busche, R.M. Chem.Eng.Progr.47(1)29-38 Jan.1951

SPRAY DRYING OF SANTOMERSE I. Investigated in a laboratory spray dryer. The study covers the effects of operating variables on bulk density and moisture content of the dried product. Operating characteristics investigated were:- (1) Addition of organic solvents, acetone and methanol (2) Temp. of the feed (3) Concn. of the feed, (4) Atomising pressure (5) Temperature of the drying medium. Product characteristics are correlated as a function of the operating variables, and their relation is discussed. Conclusions:- (1) M. content and bulk density decrease with increase in temperature of drying gas to a certain limit. (2) Bulk density decreases with increase in atomising pressure, whereas moisture content increases slightly. (3) Bulk density rises with increase in feed concentration, whereas M. content decreases slightly. Bulk density decreases with increase in feed temperature. (4) Correlation is difficult for addition of organic solvents, numerous tables, curves and photomicrographs are given.

743. Sergio Kobau Ital.431,958 10/3/1948

CONCENTRATING AND DRYING JUICES, SYRUPS AND SOLUTIONS. A spray drying apparatus is described in which steam is used under a pressure of 0.05 - 0.99 Kg/sq.cm. and at 32.5 - 99°C.

744. Kuhles, W. Chem.Fabrik 293-6.,1930

IMPROVEMENT OF QUALITY BY SPRAY DRYING. Review of principles and types of dryer. Author thinks that best type is where air enters a vertical cylindrical chamber around bottom and spray nozzle is near bottom at centre and that solution is thrown upward before falling down through hot air.

745. Ladenburg, K. Redniss, A. Chem.Inds.63(4)599 Oct.1948

MODERN DRYING TECHNIQUES. 20 years ago there were few spray dryers in U.S.; there were none in Europe. 1st was for milk and whey. Now spray dryers have found their way into nearly every industry from plastics to biologicals. Operating data have been accumulated, enabling the manufacturer to design for any desired performance. Testing units are maintained to assist customers. Several laboratory and pilot plant sprayers are on the market for customers to do their own experimenting.

746. Ladenburg, K. Redniss, A. Chem.Ind.63(4)600 Oct.1948

MODERN DRYING TECHNIQUES. NYRO DRYER. Sterile spray drying of penicillin, streptomycin, and blood. The form of the final product makes the spray dryer unique. (Sprayed as a mist).

747. Lewis, H. Ind.Chemist 10,439-41,499-501; II,71-75 (1934-1935) Nov.Dec.Feb.

THE PRINCIPLES OF SPRAY DRYER DESIGN AND OPERATION. A review with good bibliography of subject. Discusses operation of atomizers of pressure, compressed air, and centrifugal-disc types with reln. to spray drying. See also J.Soc.Chem.Ind.46,902R(1927).

748. Lukyanov, N. Molochnaya Promyshlennost 10(2)p.14 Feb.1949

UTILISATION OF SPENT STEAM FOR SPRAY DRYERS.

749. McTaggart, E. F. Chem.Tr.Jnl.p.69 21 Jan.1949

U.S. PATENT IN 1870. For use of hot or cold gases for spraying liquids into heated chamber. V. great diff. in even atomisation and it is only since about 1920 that satisfactory spray dryers have been used commercially. Earlier ones were mostly for milk.

750. Marshall, W. R. Jnr. Chem.Eng.Progress 46(10)501-508 Oct. 1950
Seltzer, E.

PRINCIPLES OF SPRAY DRYING. PART I. FUNDAMENTALS OF SPRAY DRYING. Advantages and disadvantages. Fundamentals of Operation. Pressure atomisation. Analysis of two fluid atomisation and rotating disc atomisation. The large difference between actual and theoretical values for surface created suggests need for new methods of atomization. Analysis of drying of droplets. Photographs of various dried materials to illustrate size variations, ranges and shapes, the relations between droplet size and gas-fluid ratio in 2 fluid atomisers is presented. Fundamental properties and investigation of power relations were proposed.

751. Marshall, W. R. Jnr. Chem.Eng.Progr.46(11)575-584 Nov.1950
Seltzer, E.

PRINCIPLES OF SPRAY DRYING. PART 2. ELEMENTS OF SPRAY DRYER DESIGN.

1. Operating Variables. 7 are given and discussed, including the relations between particles size, distribution and shape, and speed etc. of atomisation and conditions of air flow, temperature etc.
2. Design and operating faults. Little is known about the complicated air currents.
3. Performance. An analysis of performance and costs. Curves are given.
4. Economics.

Discussion 30 Refs.

752. Nyrop, J. E. J.Soc.Chem.Ind. and Trans.48 136-139 1929

SPRAY DRYING AND DRYING OF DAIRY PRODUCTS. Formulae for calc. time to dry; functions of velocity of drying current, surface exposed, temperature, pressure. Types of Dryers. Niro atomiser. Spray with revolving veins and cyclone air disperser at top of dryer. By modifications of feed two types of powder produced:-

(a) Dispersion of sugar and albumin in fat, which could be moulded.
(b) Dispersion of fat in sugar and albumin gave a water soluble powder.

753. Miklos Pados Hung.P.139,954 24 Sept.1949 C.A.[illegible]. 10 July 50

RAPID EVAPORATION OF SOLUTIONS, EXTRACTS, EMULSIONS AND SUSPENSIONS, ORG. OR INORG. The filtered liquid is sprayed under a pressure of 60-300 atm. at 100-700° through a zone of gradually increasing diameter. The length of the zone should be 10-60 cms. in the case of electric heating or 100-200 cms. without heating. Spray should preferably be downward and into a vacuum if desired. Air may be led into the zone in a reverse direction and the zone heated by the friction of the air.

754. Partridge, E. P. Ind.Eng.Chem.22.1930 601-3

IMPROVED SYSTEM FOR DRYING AND RECOVERY OF PRODUCT. Air filters, air heaters, milk heater, pump, etc.

755. Phillip, T. B. Instn.Chem.Engrs.Trans.13 1936 p.107-20

FOOD PRODUCTS DEVELOPMENT OF SPRAY DRYING, Particular consideration of heat transfer principles involved, means of applying them, and results obtainable with this type of equipment; spraying devices; air heaters; recovery of dried products; properties of spray dried materials, with special reference to food products.

756. Power, C. D. Chem.Eng. & Min.Rev.20 201 (1928)

SPRAY DRYING. Advantages:- 1. Evap. Dry and disintegrate in one operation. 2. Elim. intermed. products. 3. Use any metal in drier. 4. Use flue gases instead of hot air. Applications:- 1. Easily oxidized subs. such as Cuco bases dyes and cerium chlor. 2. Easily dissoc. subs. such as synthetic urea. 3. Easily damaged ferments. 4. Subs. with delicate flavours. 5. Subs. phys. and chem. sens. to heat. 6. Org. and 7. inorg. colloid solutions. 8. Suspension. 9. Homogeneous solutions of suspensions to give uniform dry mixture. 10. Rapid cooling etc. Kestner Spray Dryer:- Heated air blown in at top, cold air down around rotary atomizer bag dust collectors where air leaves. Centrifugal motion of air. Karuse (Germ.) Rotary spray at bottom of chamber. Air enters at bottom. Some of solid falls back. Rest carried over with air to dust collectors. 2-5 lbs. steam per lb. water evap. Gray-Jensen. Spray nozzle in middle of tall cone like a dust sep. Air enters top tangentially goes half way down then up center and out dust collector on waste air used on milk.

757. Reavell, J. A. J.S.C.Ind.(Rev.)46 925-930, 951-957 (1927)

Imp. Steps. 1. Atomization. 2. Drying. 3. Separation of product. Describes several types of sprays and under - and overfeed disc atomisers. Accents importance of preventing evaporation until liquid is clear of disc. Also very imp. to have uniform size drops as capacity is governed by time to dry largest drops. If air stream goes up will get dried powder falling through hottest air and hence over heating. R. Prefers to supply air at top with rotary motion in same direction as rotation of spray so that no unreliable eddy currents are set up by joining of air current and sheet of spray uses cold air around disc to defer evaporation until drops are free from disc. Air leaves bottom at sides and goes to large number of bag filters. Should use high air temperature for high efficiency and capacity (high ΔT) but not overheat dust. When particles not uniform the smaller ones will be overheated. Kestner plant described.

758. Reavell, J. A. Trans. Inst. Chem. Engrs. 6 p.115-126. Conf. 6/12/1928
FILM AND SPRAY DRYING. A general account. Curves for performance. Data for Film Dryers. Curves for spray drying shewing relations between bulk density and atomiser speed as a linear relationship, atomiser speed and form of droplets and bulk density, and bulk density and size of particles.
The bulk density is constant until the speed is high enough to make the particles hollow. After that the particles are thin walled enough to break, and bulk density rises.

759 Reavell, J. A. Ind. Chemist 5 p.32 1929
FILM AND SPRAY DRYING. Brief abstracts of papers read before the Institution of Chem. Engineers, dealing in a general way with the subject of drying and dehydration.

760. Seltzer, E. New York Academic Press 1949 pp. 399-520
Settelmeyer, J. T.
ADVANCES IN FOOD RESEARCH Vol. II. SPRAY DRYING OF FOODS. A comprehensive review of spray drying.

761. Settelmeyer, J. T. Food Inds. 22 2 272 1950
AIR SWEEPER BRINGS DRYER EFFICIENCY. Deposition on walls of dryer is removed by air blast.

762. Slade, F. H. Chemical Products 13(5) 180-185 Apr. 1950
SPRAY DRYING DEVELOPMENTS. A general description of spray drying equipment and uses. Good diagrams of Swensen direct fired dryer, Kestner atomiser disc, Scott spray dryer, Kestner spray dryer, Rema pneumatic dryer with brief description, (similar to that in Internat. Chem. Eng. Oct. 1948., and a flow diagram of a coffee spray drying factory.
Materials:-

Soap
Coffee
Blood and derivatives
(for food and fertiliser)
Sensitive substances

Ferments
Composite solutions
Tanning Extracts
Plastics
Glues

763. Smith, D. A. Chem.Eng.Progr.45 12 703-7 Dec.49
Swenson Evap.Co.
SPRAY DRYING EQUIPMENT. FACTORS IN DESIGN AND OPERATION. The factors governing spray formation. Types of spray dryers and 5 illustrations (diagrammatic). Five operation variables are discussed. Some problems in spray drying. Confirmation of trend towards countercurrent flow and multiple jets as in soap drying.

Appl. in Food Industry
Infant Foods
Non fat milk solids
Whole milk
High butterfat cream
Ice-cream mix
Special Cheese Products
Malted milk
Soluble coffee
Soluble Tea
Pectin
Eggs, whole and albumin
Potatoes raw, cooked
Yeast
Prepared cocoa
Lemon Juice
Partially hydrolysed starch Products

764. Stewart, E. D. Chem.& Met.Eng.35 4712 28
Coarse spray of same solution used as dust collector. Substances with high solubility and high B.P. are not completely dried - form drops in product. Colloid seems to inhibit the effect. Used for 1. blood products 2. Eggs or Eggs plus skim milk 3. Gelatin 4. Soap 5. sugar or beverage powders (choc. & milk & sugar) 6. Blackstrap molasses 7. Glucose syrup 8. Inorg. salts $(Na_2 SO_4)$ Process not recommended for cheap materials. Particular importance to food and beverage industry. Apple, grape, raspberry juice.

765. Wertheimer, R. S. Paper Trade J.94 No.5 Feb.4 1932 p.49-50
DRYING PAPER ON YANKEE DRIERS. Data on drying rates and effects of air scavenging; sampling method. Before Tech. Assn. Pulp and Paper Industry.

766. Young, J. Tongue, R. G. B.I.O.S. Report 887

SPRAY DRYING EQUIPMENT. Henkel & Co. Dusseldorf. pp.2-14. Description of apparatus. Data and diagrams of spray dryers and nozzles. Tables of Data for Spray Drying of

Bleach Soda
Disodium Phosphate
Soap Powder
Hydrated Sodium Silicate
Washing Powder containing 11% mersolate
Cleansing composition.

767. Zahn, O. Chem.Ztg.54 101 973-5 17.12.1930
SPRAY DRYERS. Patents reviewed. Author's Ravo-rapid system described. Vertical cylinder. Liquid falls centrally on a rotating disc. Main air feed ascends spirally. Subsidiary air feeds assist atomisation and powder is collected at bottom. High thermal efficiency is claimed.

Equipment

768. Advt. Chem.Eng.News 28(50) p.4363 11 Dec.1950
SWENSON RESEARCH SPRAY DRYER. For Pilot Plant and Laboratory Operations. Self contained unit with instrument panel.

769. —— Chem.& Eng.News 27(38) 2728 19 Sept.1949
PORTABLE SPRAY DRYER. Niro laboratory unit, for assessing large scale performance. Stainless steel and glass. 50,000 r.p.m. atomiser head, 2-15lb. water per hour capacity.

770. A/S Niro Atomiser B.P.627,050 7.3.46
SPRAY DRYER FOR LIQUIDS OR SOLUTIONS. Systems of vanes are fitted to both gas and liquid inlets to improve distribution. The distance between the central atomiser and the gas inlet distributor must be not less than 4 inches. Cf B.P. 589,544.

771. Anon. Chem.Ind.63(6)994 12/1948
SPRAY DRYER NIRO. ½ column description. The outstanding feature is the head - a high speed rotary head which ejects the liquid as a mist. Hot air inlet just below the atomiser. Temp. is low. High bulk densities can be attained.

772. —— B.I.O.S. Report No.887
SPRAY DRYING EQUIPMENT FOR POWDERS.

773. —— Chem.Eng.News 26 51 20.12.1948
Laboratory Spray Dryer with centrifugal spray and various facilities.

774. Berg, C. Mfg.Chemist 72-75 Feb.1949.
IMPROVED SPRAY DRYING PROCESS. Niro atomiser Ltd. Copenhagen. Atomiser wheel gives uniform size droplets increasing surface area to 1,500 sq, ft./lb. instead of 50 sq.ft./lb. with a roller dryer. Permits low temperatures and high speed operation. Appln. to blood serum and washing powder.

775. Beswick, W.R. Fraser, N.C. B.I.O.S. Report No.335 94-100
KRAUSE SPRAY DRYER. by Lurgi. Description, sizes of parts etc. Also description of demonstration spray dryer. Drawings available.

776. Von Bezold. Chemische Apparatur (Berlin), 17, No.19 Oct,10,1930,pp.217-218,2 figs.
SHAFT ROTARY SPRAY DRIER (DER SCHACHT-RIESELRADTROCKNER). In this type of drier, material moves according to gravity from top to bottom, while drying air travels vertically through material, advantages of Propfe kiln over other shaft kilns, with regard to efficiency and fuel economy; example is shown of sodium chloride boiling plant with spray drier.

777. Bowen Research Corp. Food Inds. 9 1 38 1937
Hot air enters by longitudinal slots to form vortex into which material is sprayed.

778. Bowen Engg. Corp. Chem. Ind. 63(2) 260 Aug. 1948
NEW SPRAY DRYER. 5-10 tons product per day and fully automatic. Flexible. Direct or indirect heaters. Single or multi-stage dry collection and wet collection. Various atomisers. 12 foot x 2 ft. floor. Can be installed out of doors.

779. Bowen Engg. Inc. N.J. Chem. Inds. 65 6 p. 938 Dec. 1949
SPRAY DRYER. Announcement with illustrator of semi-plant size dryer, easily assembled. Headroom 23 feet. Shock cooling arrangement.

780. Danish Serum Inst. Copenh. A/S Chemical Industries 7/1948 63 No. 1
Niro atomiser. p. 30
Adaptation of one of N.I.R.O. dryers to STERILE operation by slight positive pressure and sterile warm air and packaged manually in a sterile cabinet. Illustr.

781. Manning, P. D. V. Chem. and Met. Eng., 38, No. 12, Dec. 1931, pp. 702-704, 3 figs.
REVERSED CURRENTS ACCOMPLISH TWO-STAGE SPRAY DRYING. Type of drier, developed by D. D. Peebles, consists of desiccator chamber from 8 to 12 ft. in diameter and 8 to 10 ft. high; atomizing is accomplished by centrifugal force..

782. Moore et. al. See under "Fruit Juice".
SPRAY DRYING DID NOT GIVE SATISFACTORY CITRUS JUICES.

783. Murrey, D. J. Food Inds. 1939 11(3) 161
Mnfg. Co.
DRYER SPRAY WHEEL. Self cleaning.

784. Natuss, V. A. Andreev U.S.S.R. 68,537 31.5.1947
APPARATUS FOR SPRAY DRYING OF SOLUTIONS. The app. is particularly suitable for spray drying of milk, blood, eggs etc.

785. Niro Dryer, Niro Corp. N.Y. Chem. Eng. 56(3) 154 March 1949
The outstanding feature of the Danish development is specially designed high speed rotary atomising head, producing a mist. Product continuously removed from bottom of chamber. Consistently uniform powder at low temperatures with extremely high bulk densities when required. Diagram.

786. Oetken, P. A. Chem. Ztg. 25, 901-2(1931).
SPRAY DRYING IN THE KREUSE SYSTEM. Description of a German spray drying system employing a rotating disk sprayer and any of several arrangements of air inlet disk drive and bag filter.

787. Reavell, J. A. B.P.503,737(April 13th,1939).
IMPROVEMENTS IN OR RELATING TO SPRAY-DRYING APPARATUS. A spray evaporator is provided with filtering units inside the evaporating chamber to remove the powdered product from the issuing drying medium, the units being so arranged that they can be operated periodically in turn to release the powder.

788. Sulzer Co. Sulzer Technical Review No.3 pp.19-26
L. Piatti 1950
SPRAY DRYING. General Description of the Sulzer spray dryer employing the Sulzer spray disc. Diagrams and illustrations and photographs of particle types and of agglomeration produced by wrong physical characteristics of the solution. Microtome sections shew construction of the particles.

789. Swenson Evaporator Co. Chem.Engg.News 27(10)671 7 Mar. 1949
Diagram of Spray Dryer for Sulphite liquor..

790. Waite, R. Chem.& Ind. 1940,59,659.
LABORATORY SPRAY-DRYING MACHINE. Describes constructional details and performance of a laboratory model of a spray-drying machine, which has been used to provide small samples of milk powder, prepared under controlled conditions and containing various added substances, and also for the drying of skim and whole milk, egg yolk, blood corpuscles and plasma, and grass juice.

791. Woodcock, A.H. Tessier, H. Canad.J.Res.A,1943,21,75.
A LABORATORY SPRAY-DRIER. Describes a laboratory model of a cyclone type of spray drier. The main drying chamber is an inverted cone, 2 ft. in diameter at the base and 5ft. 2in. in height. Adjustments are provided for inlet air temperature, total air flow, angular velocity of air in the drying chamber, quantity of liquid introduced and spraying technique. The drier has been found practical in operation and has produced dried egg and dried milk equivalent to the best produced commercially.

792. SPRAY DRYING. See also under.
Egg - Green. Conrad.
Fruit Juice - Moore
Yeast - Farrall
Orange Juice - Schwarz and Penn
Blood - -
Penicillin - -

Atomisation

793. ---- Science Library Bibliographical Series No. 58 1932
THE BREAKING UP OF LIQUID JETS AND DROPS UNDER THE ACTION OF GRAVITY. 57 refs.

794. ---- B.R.B.Note No.T.C.1118.D.S.I.R./2315/9.
295/6.1949
FORMATION OF SPRAY BY TWO IMPINGING JETS. The report describes some investigations into the behaviour of sprays produced by a pair of impinging jets, $\frac{1}{8}$ inch diameter with variation of angle, distance, and water pressure.

795. Anon. Film & Shell Petroleum Co. ATOMISATION. 1949
Methods of producing atomised liquids and of recording.

796. Adler, C.B., Amer.Inst.of Chem.Engrs.Ann.Meeting.
Marshall, W.R. Dec.1950
ATOMISATION OF WATER WITH SPINNING DISCS. The following characteristics were studied:- 1. Drop-size distribution. 2. Spray weight distribution and 3. Power requirements. Drop-size data were obtained for a variety of disc designs. Effects of feed rate and disc speed on power requirements and spray distribution were obtained. The liquid used was water. Mathematical analysis of flow characteristics.

797. Adler, C. R., Mark, A. M., Amer.Inst.of Chem.Engrs.Ann.Meeting.
Marshall, W. R., and Dec.1950
Parent, R. J.
AN ELECTRONIC DROP-SIZE DISTRIBUTION ANALYSER. A scanning instrument enables resolution into 15 drop size classes. 10,000 drops can be scanned, counted and classified in about 30 minutes.

798. Bate, Fog, Nozzle Co., Chem.Engg. p.135.Oct.1949
Greenfield, Mass.
SPIRAL NOZZLE ILLUSTRATED. The spiral shears a single high velocity jet.

799. Binks Mnfg. Co. Bulletin
3122, Carroll Ave.,
Chicago, 12. Ill.
Standard Spray Nozzles available in 17 sizes to fit ¼ to 2½ inch pipe connection. Stainless Steel. Flow around a 2 vane helix which sets up 2 rotating jets.

800. W.E.Comings, C.H.Adams, Ind.Eng.Chem.40. 74.1948
E.D.Shippee.
ATOMISATION OF LIQUIDS, with High Velocity Vaporisers.

801. Dimmock, N. A. Nature 166(4225)Page 686.21 Oct.1950
PRODUCTION OF UNIFORM DROPLETS. Describes an apparatus for producing and studying the formation of uniform droplets. The drops are made to issue from a magnetically operated vibrating reed. Measurement of droplets was made after falling into an oil.

802. Doble Engineering 159. 21, 61, 103, 1945
The design of spray nozzles to give sprays of defined characteristics. Effect of change in viscosity of liquor.

803. Doble, Halton. Proc. Inst. Mech. Engrs. 157, 103. 111. 1947
A theoretical treatment of the design characteristics of spray nozzles.

804. Edeling. C. Angew. Chemie Biehefte. 57, 1-54. 1949
IN A THOROUGH ARTICLE, CONTAINING MUCH EXPERIMENTAL DATA, EDELING HAS PROPOSED A SOUND APPROACH TO MANY OF THE PHENOMENA OF SPRAY DRYING. He investigated the factors influencing the design of a two-fluid nozzle for atomisation, and determined the effect of the physical properties of the liquid on the maximum drop size from such an atomiser. Equations for the motions of the spray particles in a typical idealised dryer were developed and the time required for a particle to pass from the atomiser to the dryer wall was calculated for several cases. Methods for estimating the time to dry a drop to dryness were presented.

805. Edeling, C. Chem.-ing.-Tech., 1949, 21, 137-138
SPRAY-DRYING. Spray produced by pulverisation of the liquid in a gas stream of high velocity contain droplets of sizes distributed normally about a mean. For small plants, the droplets size must be correspondingly reduced. The energy required is far greater than that needed to overcome surface tension.
The distribution of droplet size follows the laws of probability and the conditions at the nozzle. The surface of droplets of 1/10mm. diam. is about 10m^2 per litre of liquid. The energy for atomisation is 25 to 100 times the value calculated from surface tension. The heat exchange is greatest when the droplets do not break. The coefficient of heat exchange is 4 to 10 times that calculated for plane surfaces.

806. Finnecome, J. R. Mech. Wld., 11 Oct. 1946, 120, 416-21
FLOW THROUGH STANDARD NOZZLES, ORIFICE PLATES AND VENTURI TUBES - II. Discharge coefficients of nozzles, sharp-edged orifices and venturi tubes are summarised in a number of tables and graphs, as are compressibility factors for air and steam.

807. Fogler, B. B.,
Kleinschmidt, R. V. Ind. Eng. Chem. 30 (12) 1372 - 1384. 1938
SPRAY-DRYING. A description of the apparatus, process, and methods of spray formation, pressure, two fluid and centrifugal system. Photomicrographs of hollow particles and spark photographs of spray formation for thin and viscous liquids. Drying the particles. Factors controlling the efficiency of spray-drying.
Performance data for representative materials. Heat required per lb. water evaporated = 2,250 B.T.Us. up to 3,800 B.T.Us. Bibliography and review of 29 U.S., 3 British and 2 German patents.

808. Friedman, S. J., Gluckert, F. A., and Marshall, W. R. — Amer. Inst. Chem. Engrs. Ann. Meeting. Dec. 1950
CENTRIFUGAL DISC ATOMISATION. Use in spray dryers, humidifying equipment and oil burners. The results of an investigation with a number of typical centrifugal discs shewed that drop-size distribution and power consumed by these discs could be predicted. Correlation with data recorded by other investigators.

809. Glendenning, et. al. — Trans. Amer. Inst. Mech. Engrs. 61. 373. 1939
The qualitative effect of change in viscosity on the discharge coefficient of a spray nozzle.

810. Greene, J. W., Conrad, R. M., Olsen, A. L., Wagoner, C. E. — Chem. Eng. Progr. 44. 591-602. 1948
Results obtained with spray dryers employing pressure nozzles for atomisation were presented complete with material and heat balances.

811. Hodgkinson, J. Ltd. (Salford) Felsner, O. — B.P. 624,999, 27.7.47
SPRAY NOZZLES FOR VISCOUS LIQUIDS (FUELS). Liquid enters a circular chamber behind the nozzle by a series of tangential tubes so that the issuing jet is rotating, and so giving a better atomisation.

812. Joyce, J. R. — J. Inst. Fuel. 22 (124) 150-156. Feb. 1949
THE ATOMISATION OF LIQUID FUELS FOR COMBUSTION. A consideration in detail of the mechanism of atomisation. Reference to theprincipal types, and detailed description of the pressure jet type. The liquid-fuel conbustion is a vapour phase process. The performance of the jet is impaired by slight errors in proportions, e.g., obliquity of orifice, roughness and irregularities in flow passages. Droplet size is decreased by pressure and increased by viscosity. Numerous diagrams of nozzle design.

813. Lewis, H. C., Edwards, D. G., et. al. — O.S.R.D. Rept. No. 6345. Nat. Res. Council Insect Control Cttee. No. 148. 1945
A STUDY OF THE ATOMISATION OF LIQUIDS. II. ATOMISATION OF LIQUIDS IN HIGH VELOCITY GAS STREAMS.

814. Lewis, H.C., Edwards, D.G., Goglia, M.J., Rice, R.I. and Smith, L. W. Industr.Engng.Chem.Jan. 1948. vol.40, 67-74

ATOMIZATION OF LIQUIDS IN HIGH VELOCITY GAS STREAMS. Attention is called to the general usefulness, for purposes of design and control, of the empirical equations recently published by Nukiyama and Tanasawa. The mathematics of the equations is discussed, and it is shown that drop size distribution data can be expressed in terms of a simple straight-line relation. In the case of gas-atomizing nozzles, analysis of the data in the literature reveals substantial agreement with the equations. In the case of liquid spray nozzles the agreement of the equations is more qualitative. Experiments on gas-atomizing nozzles are described. These corroborate and extend the work of Nukiyama and Tanasawa and give an indication of the effects of gas density, gas viscosity, heat transfer from gas to liquid, and the scale of the apparatus on the performance of gas-atomizing nozzles. D. A. Smith comments:- Valid for low outputs but there is no evidence of validity for high outputs.

815. Littage, G. Compters Rendus 1943

217(4) 99-100. Theory of spray formation from jets of liquid.
217(15) 340-342. The atomisation of a liquid jet.
Transl. from the French by W. J. Baker.

816. McEntee Amer.Soc.Mech.Engrs.Meeting, April, 1950

METHODS OF ATOMISATION IN SPRAY DRYING. Atomising equipment and theories of atomisation are discussed.

817. May, K. R. J.of Applied Physics 20.10.pp.932-8 Oct.1949

AN IMPROVED SPINNING TOP HOMOGENEOUS SPRAY APPARATUS. An apparatus is described and illustrated which produces homogeneous mists or clouds of solid particles of any desired size. As in Walton's original model, liquid is sprayed by a Beams high speed air driven top, but an improved performance has been achieved by utilising a property of high speed air films, so that automatic extraction of unwanted satellite droplets, simple construction and low air speeds are obtained. Distribution hystograms. Quotes: K. R. May J.Sci. Instr. 22.187.1945. W. H. Walton and W. C. Prewitt. Proc. Phys. Soc. (in the press). J. W. Beams. J. Appl. Phys. 8.795.1937.

818. Mayer, H. FIAT Rev.German Sci.Physics of Liquids and Gases. pp. 52-57. 1948

LIQUIDS: EVAPORATION AND CONDENSATION. MECHANISM OF DROPLET FORMATION.

819. Monarch Mnfg.Works. Catalogue No.6
Philadelphia.
Tables of capacities of various orifices, and operating details.

820. Novikov, I. I. Engrs.Digest.X(3)72-3.March 1949.Transl. from Russian.
ATOMISATION OF LIQUIDS BY CENTRIFUGAL NOZZLES. Tangential Inlet. Mathematical treatment. There is not much in the way of experimental data to be found in the voluminous literature on centrifugal nozzles. Nevertheless by collating those available, it is possible to plot a curve for an equation giving the relation between the diameter of the droplets and the other data for the nozzle.

821. Nukiyama, S. & Trans.Soc.Mech.Engrs.Japan.4.86.No.14.1938
Tanasawa, Y.
Considerable work has been done to reduce the process of atomisation to fundamental equations. Above authors' equations for both particle size and distribution offer the closest correlation, and were developed from work done on small two-fluid nozzles. Validity confirmed by Lewis and Edwards, 1945, and found to be valid for pressure and for 2 fluid atomisation, for quantity of gallons per hour. No data, however, that they are valid for gallons per minute, although they may be.

822. Parent, R. J. & Science News Letter 56(15)232.1949
Schumm, R. W.
SPRAY DRYING CONTROL. An electronic device that automatically sorts and counts liquid drops shot out at the nozzle of a spray-drying machine has been constructed at Wisconsin University. The purpose of the instrument is to shew what nozzle adjustments are needed to obtain a soap of uniform quality. It can be used to measure uniformity of spray in fuel injection. No adequate data have existed on the character of sprays.

823. Rosin. Rammler J.Inst.Fuel.10.34.1936
Analysis of drop-size distribution.

824. Sauter, J. Forschungs Gebiete Ingenieurw No.312 1928
Considerable work has been done in the atomisation of water. As the relative velocity differences increased, the diam. of the droplet decreased until a constant particle size was approached. This leads to the conclusion that there is a maximum disc speed or maximum pressure, which when exceeded causes needless power expenditure.

825. Slade, F. H. H. & V. Engr.21(251)479.1948
ATOMISER SPEEDS. Disc Atomiser at low speed gives solid spherical particles which decrease in size as speed increases. At higher speeds, particles become hollow with decrease in bulk density. At higher disc speeds they break up, thus slightly increasing the bulk density. Illustrations. The above holds for solutions but not for suspensions.

826. Stephanoff, N.N., U.S.P.2,413,420,31/12/46
Assr. to Thermo-
Plastics Corp.
SPRAY DRYING BY HIGH VELOCITY JET. Deposition of dried material is prevented in the vicinity of the nozzle by an improved nozzle arrangement.

827. Stoker, R. L. J.Appl.Phys., Apr.1946, 17, 243-5
METHOD OF DETERMINING THE SIZE OF DROPLETS DISPERSED IN A GAS. A method applicable to determining droplet sizes in the interior of an already existing atmosphere of fog or mist is developed and described. The method makes use of the fact that if droplets strike a suitably coated surface without wetting the surface, a track of the contact area is formed. A criterion is derived and experimentally evaluated for relating the droplet diameter and the track diameter. An apparatus for utilizing this method is briefly described.

828. Tate, R. W., and Amer.Inst.Chem.Engrs.Ann.Meeting.Dec.1950
Marshall, W. R.
ATOMISATION WITH CENTRIFUGAL PRESSURE NOZZLES. Performance data on spray distribution and droplet size distribution were obtained for a range of pressures, orifice diameters and spray cone angles. Correlation shewed that tangential velocity was requisite for fine atomisation. Effects of cone shape and nozzle edges were investigated. Cone angle was found to be a function of the number of inlet passages and their angle with the swirl chamber.

Evaporation

829. Bradley, Evans and Proc.Roy.Soc.1946.186.368-90
Whytelaw-Gray.
RATE OF EVAPORATION OF DROPLETS. Evaporation and Diffusion coefficients under vacuum for droplets of Dibutyl phthalate, butyl stearate.

830. J. Birks, Bradley, R. S., Proc.Royal Soc.198(1053)Aug.1949
Shellard, A. D.
RATE OF EVAPORATION OF DROPLETS. Part 2. Influence of changes of temperature and of the surrounding gas on the rate of evaporation of drops of di-n-butyl phthlate. pp.226-238. Part 3. Vapour pressures and rates of evaporation of straight chain paraffin hydrocarbons. Pp.239-251.

831. Penner, S. S. J.Physical Colloid Chem., 52, 367, 1948
THE MAXIMUM POSSIBLE RATE OF EVAPORATION OF LIQUIDS. An equation is obtained for the maximum possible rate of isothermal vaporization of liquids. It is shown that the resulting relation for the decrease of droplet radius with time gives results of the same order of

magnitude as the relation obtained from the kinetic theory of gases: Assumption of the validity of the new treatment for determining the maximum possible rate of evaporation permits an independent determination of the free volume of a liquid. (2 tables.)

832. Pleteneva, N. and Rehbinder, P. — Acta Physiochim.U.R.S.S.,1947,22,1-12

SPHEROIDAL WATER DROPS: EVAPORATION; EFFECT OF SURFACE-ACTIVE SUBSTANCES. The effect of surface-active substances on the evaporation of water drops in the spheroidal state has been investigated. A sharp decrease in the rate of evaporation of drops, $V_0=R/r_0$ (where R is the radius of the drop and r_0 the time of complete evaporation) is observed in the vicinity of the temperature, t_s, at which the spheroidal state is reached, and this temperature is found to decrease appreciably. Aqueous solutions of sodium oleate exhibit characteristic deviations from the invariance of the quantity r_0/R observed for pure water. The possible reasons of these deviations are discussed. Additions of a less volatile organic substance to water - a hydrocarbon oil - produce a shift in the temperature, t_s, at which the spheroidal state sets in, in the direction of higher temperatures, this being due to the increase in the rate of evaporation of drops with increasing concentration of the oil.

833. Ranz, W. E. and Marshall, W. R. — Amer.Inst.Chem.Engrs.Ann.Meeting.Dec.1950

DRYING OF DROPS. An experimental study of the rates of heat and mass transfer of liquid drops both with and without dissolved solids present. By the use of fine thermocouples important new data were obtained and a further approach to the problems of spray drying.

USE OF SOLAR HEAT

834. Altenkirch, E. — Z.Ver.deut.Ing.1938,82,1347-8

DRYING PLANT UTILISING SOLAR ENERGY. A description is given of a drying process in which the damp material is stored in a specially designed shed where it is exposed to a current of air previously dried by absorbent material. The air circulation and regeneration of the absorbent are caused by the heat from the sun. The method is particularly suitable when large quantities of material such as timber in saw mills are to be kept dry in store.

835. Aubele, W. W. Heat, Piping and Air Condg. 20(6) 116-126. 1948. Br. Abstr. III. 316. July 1949

SOLAR AND TOTAL HEAT GAIN THROUGH DOUBLE FLAT GLASS.

836. Dunkak, E. B., Davison Chem. Corporation U. S. P. 2,462,952, 1/3/1949. Chem. Abstr. 4403. 10/6/1949

DEHUMIDIFIER FOR SILICA GEL USING SOLAR ENERGY. The device, a large roof shaped surface preferably of Aluminium, painted black, is provided underneath with ducts for free air circulation, and utilises the pressure differential between the enclosed air and the atmosphere for creating the drying air current. Lenses or mirrors may be employed to increase the sun-ray deflection.

837. Jenny, J. Schweiz. Z. Obst-u. Weinb. 1943, 52, 492. Hort. Abstr., 1944, 14, 50.

AUSNUTZUNG DER SONNENWARME ZUM DORREN. A simple apparatus for sun-drying fruit has been designed at Wadenswil, Switzerland.

838. Osteotag, A. Schweiz. Bauztg, 1947, 65, 426, B. C. U. R. A. mon. Bull., 1949, 13, 58

SUTTER-ADANK SOLAR HEAT ACCUMULATOR. An experimental installation for heating H_2O by solar radiation in a pipe system laid out on a roof, storing it in an underground tank, and using it in a central heating plant is described.

839. Parmelee, G. V. Heat. Pip. Air Condit., Oct.-Nov. 1945, 28, 562-73

TRANSMISSION OF SOLAR RADIATION THROUGH FLAT GLASS UNDER SUMMER CONDITIONS. This paper is a mathematical analysis of the transmission and absorption characteristics of unshaded unfigured, smooth, flat glass for direct radiation from the sun and scattered radiation from the sky. The results are presented in the form of curves for single and double glass of all degrees of transmissivity and include the highly transparent types such as ordinary window glass, as well as those types, such as the so-called heat absorbing glasses, which are strongly absorbent in the infra-red. Charts are presented showing the rate of heat transfer to the interior from the surface of the glass, as influenced by the indoor and outdoor temperatures and by the amount of solar energy absorbed by the glass. The transmission characteristics of some typical window glasses are given together with data on the intensity of the direct solar and sky radiations. A sample problem illustrates the use of the information given.

840. Proctor, B. E., and Sluder, J. C. Q. M. Research Reports, 1943, 1. 73-76

SOLAR DEHYDRATION.

841. Telker, M. Minor Raymond, E. — Ind.Heating Engr.12(54)119-23.4/1950
STORING SOLAR HEAT IN CHEMICALS. The medium is No.$_2$SO4 and required amount of water and small amounts of crystallisation promoters and corrosion inhibitors. Data on heat collection are given.

TRAY DRYING

842. Hass, Frieda. — Nitrocellulose 2,207,1931,Oct.10
A NEW RAPID DRYING APPARATUS. Dryer manufactured by Frieda, Hass. Air circulation over trays by means of turbo-blower.

843. Arsdel, W. B. Van — Proc.Inst.Food Tech.,1943,p.45
TRAY AND TUNNEL DRYING METHODS AND EQUIPMENT. Types of drier suitable for different purposes are indicated and the basic requirements of a good tray drier are enumerated. The counter-flow tunnel type is used in the drying of fruit and vegetables; vegetables require higher temperature and velocity of air than fruit. The parallel-flow and cross-flow types and variations on the counter-flow type are mentioned and probable future developments are discussed.

844. B'ham & Blackburn Construction Co. Ltd. — Nature 165.4195.25 March 1950
THE UNITHERM DRYER. 100 trays of 400 grams of 20% Moisture material. Heating and ventilating system; uniform drying. Control ± 2°C up to 105°C.

845. Erimescu, P.
TRAY DRYERS. See under Coal.

846. Fisher, E.A., Buck, L., & Fleming, M. T.
1. J.Soc.Chem.Ind.54.343T.1935
2. Text Res.6.373.1936.
3. Amer.Dyes.Rep.37.333.347.1948

General. Including Effects of temperature humidity, and air speed.

847. Goodall, C. — B.P.574,158/1945
DRYING GRAINS, GRASSES, VEGETABLES, ROOTS AND THE LIKE. The invention comprises the combination of a table adapted to permit an upward flow of air therethrough and to support the material to be dried, means for imparting vibratory movements to the table and a chamber through which air can be supplied to the underside of the table.

848. Schaffner, R. M., Coull, J. Industr. Engng. Chem. Anal. Ed., 1942, 14, 590
A TEMPERATURE-AND HUMIDITY-CONTROLLED DRIER FOR A CHEMICAL ENGINEERING LABORATORY. Describes the construction and operation of a tray drier suitable for research and instruction purposes.

849. Shepherd, C. B., Hadlock, C. Ind. Eng. Chem. 30 (4) 388-397. Apr. 1938
Brewer, R. C.
DRYING MATERIAL IN TRAYS. Concerns the tray drying of surface moisture from non-hygroscopic materials. The effects of various drying conditions and depths on the constant drying rates have been studied using sand and water on trays. With sand nearly all the water was removed at constant rate and rate was nearly identical for sand and water. Rates are expressed as heat transfer or mass transfer coefficients between surface and air. Rates vary with 0.8 power of air velocity. The heat transfer coefficient is preferable for use. Data from insulated trays serve to predict rates for uninsulated trays. If critical moisture content is low, the drying time may be calculated approximately: Curves, Tables, and mathematical analysis are given.

850. White, A. S. Chem. Age. Ldn. 1946; 55. 597-8
A good discussion of tray dryers giving economic details.

851. White, A. S. Fuel and Future, Ministry Fuel Pwr., vol. 1,
288-290; London: H. M. S. O., 1948
DRYING OF CHEMICAL PRODUCTS BY ATMOSPHERIC TRAY DRYER. The author discusses briefly some factors in the design and operation of atmospheric tray dryers of the steam heated type which affect steam usage. The principal defect of these dryers is that drying is not uniform throughout the dryer. In low temperature drying non-uniformity of drying and sometimes spoilage of product can be attributed to direct radiation from the heating elements. External air heaters are the best solution. Improvement in uniformity of drying really requires drastic re-design. The biggest savings in steam and in overall drying cost can be obtained by reducing the amount of water charged to the dryer. Reference is made to the "through circulation" dryer in which hot air is passed through the mass instead of over it. Radiation losses account for a third or more of the total steam used, a four rack dryer uses about 40 lb. steam per hour at 100°C, to cover radiation losses. The majority of dryers have the economical amount of lagging. The total costs of drying varies inversely as the 1.25 power of the solids content of the pastes for the drying of dyestuffs and pigmeats at 100°C.

TUNNEL DRYING

852. Anon. Ind. Chemist (1921) March and April
CHEMICAL ENGINEERING CHARTS. 1. Drying Tunnels and Chambers (Steam Heated). 2. Influence of Variation in Air Temps. and Velocity on Rate of Evaporation.

853. Barshcherski, R. A. Stek. Keram. Prom. 6. 14. 1947. Brit. Ceram. Abstr. 215A. 1948. B.I. Nov. 1948. 573
IMPROVING THE EFFICIENCY OF TUNNEL DRYER. Linen baffles or metal dampers to deflect hot air from top to bottom.

854. Birdseye, C.
BAND DRYER. See under Food.

855. Gak, B. N. Stek. Keram., 5, No. 6, 14, 1948
THE CONTROL OF COUNTERCURRENT TUNNEL DRYERS. The effect of altering the method of supplying and removing hot air to and from a tunnel dryer was studied. The system could be altered according to the length of the tunnel dryer. The direction of air flow is both along and across the dryer. The rate of air flow, the temperature, relative humidity and rate of moisture removal, when the dryer is working under a small negative pressure, depend to a considerable extent on the method of supply and removal of the hot air. Experimental data enable the most efficient conditions of operation to be determined for any material having known drying properties. The most favourable temperature curve and the best conditions of relative humidity and rate of moisture removal for clay of the Kuchin type (which has an average sensitivity on drying) was obtained by introducing the hot air into the lower part of the dryer over one-third of the length of the tunnel; at the same time the moist air was removed from the top of the dryer. Two methods are described for supplying hot air to and removing moist air from a section of the tunnel equal to one-third of its length. The supply of hot air from below while the moist air is removed from above leads to rapid removal of the moisture; this arrangement, however, gives a rather slow rate of moisture removal during the initial drying period. The supply of hot air from below, while moist air is removed from below at the same time, along a third of the length of the dryer, is recommended on account of the need to have a high moisture content in a long section of the tunnel in the initial drying period; this is to give a delayed drying. The experimental data allow alternative systems to be chosen to meet other sets of conditions. (7 figs., 2 tables).

856. Garve, T. W. Bull. Amer. Ceram. Soc., Aug. 1948, vol. 27, 299-300
ACCELERATED RADIATED HEAT DRIER. The author describes progressive tunnel driers with combustion gases as indirect heating mediums. An improved design is presented having greatly increased radiating surface and additional air circulation.

857. Henley, A. T. Trans. Inst. Chem. Engrs. Vol. 6. p. 102-114. Conf. 6. 12. 1928

TUNNEL AND STOVE DRYING. A general account, including diagrams, charts, and plant layouts. Materials include fruits, painted articles, coated paper, etc. Air conditions are given.

858. Duncan, D. M., Wright, F. S., Jackson, A. S., & Heyne, C. A. U. S. P. 2, 393, 521/1946
Ass. to Owens-Illinois Glass Co.

DRIER. A heating apparatus comprising a horizontal open-ended tunnel, a travelling conveyor extending along the tunnel in position to convey articles through the tunnel, the tunnel comprising a row of burner blocks extending along one side thereof and having inner vertical faces forming a portion of the inner wall surface of the tunnel, the burner blocks being formed with a multiplicity of closely spaced channels extending through the blocks in a direction transverse to the faces, the channels being symmetrically arranged and of predetermined size and shape, and means for supplying fuel gases to the channels.

859. Richardson, W. D. Jl. Amer. Ceram. Soc. 12 761-4. Dec. 1929.
Jl. v. 12, p. 761-64, Dec. 1929.

GREATER EFFICIENCY IN TUNNEL DRIERS. 2 figs.

860. Ridley, G. B. Ind. Eng. Chem. 1921. 13. 453-460

TUNNEL DRIERS.

861/2. Schmidt, C. Tonind. Ztg., 66, 439, 1942

THE FUNCTION OF THE AIR IN DRYING. The heat consumed in a hypothetical tunnel dryer, working at a range of temps. of 20-100°C., is analysed in a diagram consisting of three curves, The first curve shows the heat necessary for simple vaporisation of the water; in the second that necessary to heat the drying air is included; and in the third allowance is made for heating clay and pallets, etc. It is assumed that the drying air receives no addition of heat after it enters the tunnel and that it is fully saturated when it leaves. The second curve shows a continuous drop in the heat consumption as the temperature of the drying air is raised, but the third curve has a minimum at an exhaust air temp. of 30°C. and increases fairly rapidly thereafter. The author prefers to operate at 35°C. (air entering at 95°C.) with an appropriately smaller power consumption for air circulation. He gives the heat requirement of an efficient tunnel dryer as 840 kcal/kg evaporated water and of a chamber dryer as 1,300 kcal/kg.

TURBO-DRYERS

General

863. Anon. Chem.Eng.News 29(8)697.19 Feb.1951
DRYER FOR HEAT SENSITIVE MATERIALS. The air is heated by an external steam heating unit in the Wyssmont Co. Turbo-Dryer in order to prevent fouling of the heaters.

864. Jenkins, R. & Co. Engng.136,710-2(1933)Dec.29.B.P.368,395
VERTICAL CENTRIFUGAL DRYER. A revolving column of over a dozen plates, which throw the material against stationary cones to fall to the next lower plate. An upward air current in the housing effects the drying.

865. ---- Edgar Allen News.28(326)352-3.D.S.I.R. Library
ROTARY DRUM DRYERS. Section on Turbo-Dryers with steam at 5-150 p.s.i., for magnesium carbonate, starch, etc. The Buell endless carrier turbo-dryer for materials which must not be disturbed while drying. Flax straw, staple fibre, sliced roots, green vegetables, fish, bobbins, veneers and pressed products.

866. Anon. Chem.Ind.63(4)603.Oct.1948
An example of flexibility is shewn by its suitability for sublimation of materials such as naphthalene, by reversing the process.

867. Anon. Engng.v.142.n.3684.Aug.21,1936,p.197-8
ALLEN-BUELL SYSTEM OF TURBO-DRYING. Machines developed by Buettner-Werke A-G, Uerdingen, Germany; drying medium, hot air or gas, is circulated over material by fan with numerous curved peripheral blades, not unlike reaction turbine in appearance; machine consists of circular or multi-sided casing made in sections and lagged; application to drying of granulated sugar, fiber boards, plyboards or similar sheets.

868. ----
TURBO-DRYER. See under Coal.

869. Bardgett, H. C.I.O.S.Rep.Item 30, File XXXIII-17; London H.M.S.O., 1946, 6pp, 1s.
COAL DRIERS. BÜTTNER-WERKE A.G., UERDINGENKREFELD. The Buttner Turbine type (Turbinen-Ringscheiben) or steam drier, suitable for coal, is described and illustrated.

870. Crittall, R. & Co., Waldram, H. D., Reid, W. H., and Voaden, G. W. B.P.620,922. 31.1.47
CIRCULAR DRYING OVENS. A number of circular trays are mounted above each other in a cylindrical casing. Each tray is rotatable and has a segment of 45° cut out to enable the tray below to be loaded from above. Heating coils are flat and circular with 45° segments cut out as in the trays, but are not rotatable.

871. Brown, C.O., + Wyss Mont Co. Ind.Eng.Chem. 41(3)94A. Mar. 1949
EQUIPMENT AND DESIGN. Ring-shaped trays, and material is raked through slots passing downwards. Central fans with ventilating louvres.

872. Fritsche, K. Braunkohle, 1939, 38, 281-5
TURBINE DRIERS AND COOLERS IN BRIQUETTE FACTORIES. A turbine dryer and cooler used for the first time in a briquette factory are described with data relating to output and power consumption and the special advantages of the plant described are discussed. Three years experience has led to considerable modification of the original plant but the principles remain unchanged.

873. Heastie, Basil. Ind.Chemist 8, 382-3(1932); cf.
DRYING OF SOLIDS. Tests on the drying of $CuSO_4$ and NaCl in the Jenkins drier are given. A drier for material in which the principal factor is the rate of diffusion of moisture through the body of the particles consists of a vertical cylinder divided into a number of compartments by horizontal hollow plates heated by oil, water or steam, with a V cut in each, the cuts being staggered. The material is fed onto and swept over the top plate by a rotating arm attached to a central vertical shaft, and then falls through the V cut onto the next plate where a similar operation occurs. Hot air enters each compartment between the plates, and is carried across the material, discharging to an outlet duct on the other side of the cylinder. B.C.A.

Equipment

874/875. Horgan, T. J. Soc.Chem.Industry-Chem.Eng.Group & Yorkshire Sectn.Advance Paper mtg. Apr.5, 1935. p.20-34
MODERN DRYING MACHINERY. Discussion confined mainly to description of some of more important types of rotary and turbo driers.

876. Lawrence, Scott, Barnell. B.I.O.S. Report 186
TURBO-DRYER. See under Potato.

877. Parekh, K. B. B.I.O.S. 1528
STARCH INDUSTRY IN GERMANY. Firm specialises in drying equipment for starch, sugar, and other chemical industries. Turbo-dryers for starch, roller dryers for gluten and fine film dryers for treated starches.

878. Reed, F. H. & Schmidt, L. D. et. al. Washington: Dept. of Commerce, Off. Tech. Services, 1946, 6pp. $1; Coal Age, Apr. 1947, 52(4), 174
COAL DRIERS. A report by British and American investigators on a German turbine type coal drier. The machine is designed for minus 1½-in. coal and is 30ft. high and 15ft. in diameter. It is said to dry 50 to 60 tons per hour, using steam at 120-130 deg. C. or combustion gases at 220-250 deg. C.

879. Summerville J. B.P. 567, 203/1945; Woodall Duckham Abst.
DRYING APPARATUS FOR CLAY, PEAT, COKE, COAL AND OTHER MATERIALS. Drying apparatus for clay, peat, coke, coal, etc. consists essentially of a vertical circular shaft sub-divided by horizontal spaced grids into compartments, with a vertical rotating member along the axis of the shaft, operating stirrer arms over each grid. Vertical flues extend alongside the shaft, with openings to the flues from each compartment, through which drying gases are supplied to and withdrawn from the compartments; the drying gases flow horizontally across each compartment. The material to be dried is fed into the top of the shaft, and descends through the compartments, the dried material being removed at the bottom.

880. Weisselberg, A. Ind. Eng. Chem. 1938. 30. 999-1,000
113, W. 42nd St., N.Y.
VERTICAL TURBO-DRYERS. Description, Illustrations and Dimensions. A large dryer has only 1.1c. ft. per sq. ft. of drying capacity, 23 ft. diameter, 33ft. high; has a tray area of 8,000 sq. ft. in 45 shelves, and is self cleaning.

ULTRA-SONICS

881. Anon. Pulp and Paper Bull., Paper Maker, 1948, May, p. 277 (through Papermaking Abstr., 1948, No. 1, 22

ULTRASONIC DRYERS. The Ultrasonic dryer is a powerful sound-making machine. When operating, a rapidly rotating disc forces the air through holes round its rim, and this air is cut by vanes in another stationary disc, the pulses passing through acoustic horns and setting up ultrasonic vibrations. These vibrations are then applied to the material (paper) to be dried, agitating it and knocking off the water.

882. Earle, C. R. Pwr. Generation, Sept. 1948, vol. 52, 86, 88, 132, 134, 136

WHERE WILL ULTRASONICS FIT IN POWER FIELD? Discusses possible applications for instance recovery of liquid or solid particles from gas streams; soot-blowing; water treatment; carbon-black collection; chemical recovery in paper mill; paper drying; and metal testing and soldering.

VACUUM DRYING

883. —— Ind. Eng. Chem. May, 1948. 40 (5) 778-847

SYMPOSIUM ON HIGH VACUUM. 14 PAPERS.

884. Anon. Farben Chem. 3, 531-5, 1932, Nov.

A trip through the Testing Laboratory of Vacuum-Trockner G.m. C.H. at Erfurt.

885. —— Atlas A. S. (Denmark 25/10/43) B.P. 603, 970, 19.11.45. B. III. 444. Dec. 1848

METHODS IN THE VACUUM DEHYDRATION OF ANIMAL OR VEGETABLE MATERIALS. Cellular Materials (e.g. fish, meat) in 2cm. layers at 35m.m. pressure, heated from 50° to 89°C. between platens, under pressure between the platens, sufficient for contact, but not sufficient for expressing liquid.,

e.g. for fish: 10Kg. sq.m. at start rising to 3,000Kg. sq.m.; for meat, the maximum could be 5,000 Kg. sq.m. By this means the original structure of the material is preserved, (3,000Kg. sq.m. = 4lbs. square inch.)

886.✓ Anon. Canning Age, 1943, 24, 188
VACUUM DEHYDRATION AT MARTINEZ PLANT. Describes and illustrates the Scald Association of Chicago's all-vacuum dehydration process (known as the McComb process), installed at the Martinez Food Canners' plant in California. The foods are prepared for dehydration by washing, peeling, blanching and then slicing or dicing. Dehydration is effected through the combination of heat expended from the drying shelves and vacuum provided by separate installations on each unit. The process can be used to dehydrate any form of moisture-containing matter, especially vegetables, but also fruits, meat, milk and eggs. It is claimed that foods so dried can be cooked in 3 to 15 minutes and without previous soaking.

887. Arend. Paint Techn. 1946. 11 (122) 47-9
CONTINUOUS VACUUM DRYING OF PIGMENTS. See under Pigments.

888. Baer, J. L., Guardite Corp. U.S. 2,457,116. 28.12.1948
Wilmington Del.
VACUUM DRYING. Drying materials with superheated steam, at low absolute pressure, together with application of intense radiant energy.

889. ———
VACUUM DRYING. See under Paper - Boote.

890. Brownell, L. E., Grosier, H. E. Chem. Eng. g. 56. 124-127. Oct. 1949
BLOWER AND HEAT REQUIREMENTS OF ROTARY VACUUM FILTER DRYERS. Calculations of pressure gradient across the moist portion of the cake are based on air flow, permiability and turbulence factor. Pressure drop across dry cake calculated from temperature and turbulence factor.
The previous article (Sept. 1949) told how to calculate the blower requirements of rotary drum filters. Makes use of Allerton's data. Also in Chem. Eng. 56. 112-115, L. E. Brownell and G. B. Gudz. BLOWER REQUIREMENTS OF ROTARY DRUM VACUUM FILTERS.

891. Devine, Gr. Chem. & Met. 29. 492 (1923)
VACUUM DRYING. Advantages listed:- 1. Lower heat cons. 2. Higher speed. 3. Low temperatures. 4. Prevents oxidation. 5. Prevents discolouration. 6. No odours. 7. Flexibility. 8. Small floor space. 9. No fire hazards. 10. Uniform product. 11. Recovery of solvents possible.

892. Ernst, R. C., Ridgway J. W., Ind. Eng. Chem. 1938. 30. 1119. 1122-5
and Tiller, F. M.
Unn. of Louisville
PRACTICAL VACUUM DRYING. An investigation into vacuum drying using Sil-o-Cel cake. A vacuum of 18 inches of mercury gave satisfactory drying rates. Effects of shelf temperature, degree of

vacuum and thickness of layer were studied. Large temperature differences usually at the end of the constant rate period, cause cracking, especially if the period covers a large moisture range.

893. Fisch. J.S.D.C. 16. 212, 1900. Ost. Woll. u Leinen Ind. 1900. 11
DRYING FABRICS IN VACUO.

894. Flosdorf, E. W. Food Inds. 17. 92. 1/1945
REVIEW OF VACUUM DRYING FROM THE FROZEN OR LIQUID STATE.

895. Foote, N. M. Ind. Eng. Chem. 38. 12. 1642-46. 12/1947
VACUUM TREATMENT OF PAPER FOR CAPACITORS. See under Paper.

896/7 Lavett, C.O. &
Marle, D. J. Van Ind. Eng. Chem. 13, 600-5. July, 1921
VACUUM DRYING.

898. Ledoux, E. &
Atapulgas Clay Co. Chem. Eng. 7/1948. 55 (7) 102-104
VACUUM CONCENTRATION BY VAPOUR ABSORPTION. General Description. Concerns Evaporators, etc. Author indicates that for a given power input, vacuum concentration could be carried out at a much lower temperature.

899. Martin, S. L. Ind. Eng. Chem. 30. 402-406. 1949
VACUUM TECHNIQUE AND ITS INDUSTRIAL APPLICATION. I. A review. The development of vacuum pumps and vapour diffusion pumps, vacuum gauges, degassing of the materials and equipment for the detection of leaks.

900. Martin, S. L. Ind. Eng. Chem. 30. 456-459. 1949
VACUUM TECHNIQUE AND ITS INDUSTRIAL APPLICATION. II. The advantages of vacuum conditions are listed and applications reviewed, including evaporation and distillation.

901/2 Moore, Atkins et al. Proc. Inst. Food Techn. 160-8. 1945
RESULTS WITH AND WITHOUT VACUUM DEHYDRATION. Vacuum drying did not give satisfactory citrus juices. See under Fruit Juice.

903. Schroeder and Cotton.
VACUUM DRYING. See under Freeze Drying.

904. Schwarz, H. W. Ind. Eng. Chem. 40. 2028. 1948
Development of Pilot Plant for Dehydration of Coffee Extract. See under Coffee and Orange Juice.

905. Schwarz, H. W., & Penn, F. E. Ind.Eng.Chem.40(5)938.May 1948
PRODUCTION OF ORANGE JUICE, CONCENTRATE AND POWDER. On page 938, curves are assembled on one diagram of the costs per lb. H_2O pumped at various pressures from 0.3 to 1,000 microns pressure. Cost varies from 0.01 cent to 100 cents (lb. H_2O). Costs of water removal increase sharply as pressure is reduced below 500 microns.

906. Tucker and Sherwood Ind.Eng.Chem.5/1948 40(5)832-8
VACUUM DEHYDRATION USING LIQUID ABSORBENTS. Pumping and brine absorption systems for LiCl, LiBr, $CaCl_2$, or mixtures. Diagrams of absorption systems are given and a large amount of fundamental data is presented.

907. ——— B.I.O.S. Report No.348
Vacuum Dryers for Timber. See under Timber.

908. Advt. Chem.Tr.Jnl.5/2/1950
G. SCOTT AND SONS. HIGH VACUUM CONTINUOUS BAND DRYER. For viscous liquids, suspensions, semisolids, delicate materials and foodstuffs. An experimental dryer is available at their London research stations.

909. Anderson, D. L. B.P.625,703, 4/47
VACUUM OVENS. The oven is divided into a number of separate compartments each containing 1 tray and a separate vacuum line. The hollow steam heated trays have inlet and outlet nipples which fit into the steam and condensate lines when the tray is placed in position.

910. Bailey, L. H., Stokes, F. J. M/C Co. Ind.Eng.Chem.1938.30.
Philadelphia 1008-10
ROTARY VACUUM DRYING. A short illustrated description of rotary vacuum dryers. The spiral agitator is illustrated.

911. Campbell, W. L., Proctor, B. E., and Sluder, J. G. Res.Repts. on Q.M.Contract Projects.July 1, 1944 - 31 Oct.1945.Mass.Inst.Technology.Food Tech.Labs.Cambridge Mass.

CONTINUOUS BELT DRYERS.

912. Dienst, K. B.P.516,163 December 22nd,1939).Addition to B.P.452-546.
IMPROVEMENTS IN FEED AND DISCHARGE AIR-LOCK APPARATUS FOR VACUUM DRIERS. Claims a process for feeding and discharging material in vacuum driers, using a chamber, between 2 lock arrangements, which is automatically evacuated. A limited volume of material to be dried is isolated, with as little air as possible, at atmospheric

pressure and is fed or discharged through air locks above or below the drier to or from a space or chamber under vacuum. The time between operation of the locks is such that the vacuum in this space has been brought almost or quite up to the degree of vacuum in the drier.

913. Hofner and Beck — F.I.A.T.Microfilm Reel A.28.Frames 5261-66.U.S. Dept. of Commerce.Off. Techn.Survey P.B.L.70251.27 April 1937 $1.50

VACUUM STEAM HEATING FOR DRYING CABINET

914. Hellier, E. G. — Food Inds.21.9.1191-3.1949

HIGH VACUUM BELT DRYER IMPROVES THE PRODUCT. Diagrams of various belt dryers. Operations described and costs are given. Food retains its properties better in vacuum.

915. Holland-Merten. — Chemiker-Zeitung, vol.55, No.16, Feb.25, 1931, pp.153-154, 6 figs.

NEUES UEBER VAKUUM-TROCKENSCHRAENKE (NEW VACUUM DRYING CABINETS). Factors governing design; superiority of square over round-shaped cabinets; examples of recent designs of vacuum drying cabinets.

916. Ladenburg, K. & Rednisc, A. — Chem.Ind.63(4)601-2.Oct.1948

MODERN DRYING TECHNIQUES. A long description of rotary vacuum dryers. Advantages:- Similar to vacuum cabinet dryers but faster. Disadvantages are:- Cost, cleaning for different products. There is little information and practically no data to enable a competent engineer to design for a new product. No present advances have been made. Recent improvements have been on the side of agitation economy and drying rates.

917. Leyland, J. — Chem.Tr.Jnl. 124.No.3224.18 March 1949 P.311-2

VACUUM PROCESS TECHNOLOGY. Design and Construction of Plant. Strength of coned and dished bottoms. Results of tests on closures, gaskets, etc.

918. Lyle, O. — M.E.R.O.Heat Transfer and Heat Exchange App. Cttee.Paper No.H.T/H.E.29

THE BAROMETRIC JET CONDENSER. The report compares the advantages of the barometric jet condenser and the surface condenser. D.S.I.R./4486/N.S.

919. Miag Mühlenbau Und Industrie Akt.-Ges. — B.P.521,[illegible](May 20th. 1940.Brit. chem.physiol.Abstr.B.1940, p.649

IMPROVEMENTS IN APPARATUS FOR DRYING, STERILIZING OR OTHERWISE TREATING MATERIALS SUCH AS LIQUIDS OR GRAIN UNDER VACUO. The air-locking device comprises mushroom valves and a rotary measuring feeder, operated in synchronism with such rapidity that the process may be considered continuous.

920. Pfeiffer, D. C. & Hill, J. M. U.S.P.2,374,232,24.4.45.B.I.118 Feb.1949
CONSTRUCTION OF A DRYER. Includes a desiccant which heats and imparts heat to the material to be dried, e.g. calcium sulphate.

921. Riley, G. W. Trans.Ind.Chem.Engrs.6.145.1928
VACUUM DRYERS.

922. Smith, G. F. & Rees, O. W. Indus. and Eng.Chem.,vol.23,no.12, Dec.1931,pp.1328-1330, 4 figures
DESIGN AND CONSTRUCTION OF SPECIAL VACUUM-DRYING APPARATUS FOR DEHYDRATION OF PRODUCTS WITH LOW VAPOUR PRESSURE. Use of special condenser with mechanical-refrigeration unit,brine immersed, as regeneration unit for commercial drying of gases using reagent anhydrone is suggested.

923. Stokes, F. J. M/C Co. Chem.& Eng.News 27(9)646,28.2.1949
VACUUM SHELF DRYER. High Speed in low micron range. Stainless steel dryer shelves with internal baffles. Drain gutter, swivel spotlight. 5 sizes, steam, hot water or oil heating.

924. Stokes, F. J. M/C Co. Chem.Eng.g.56(2)160.1949
ROTARY VACUUM DRYER. Nine sizes 1c.ft. to 600 cubic feet working capacity. Spiral agitators. Complete discharge. Shell, shaft and agitator arms are heated. Dust filters, rotary vacuum seal, quick opening doors.

925. Taylor, H. F. Food Inds.8(12)608-11.651.1936
A vacuum drum meat dryer did not work in a fish drying plant. Motors overloaded. The difficulty was overcome when construction of paddles was modified and other changes made.

Fundamentals

926. Guthrie, A. Wakelin, R. K. McGran Hill.N.Y.1949
VACUUM EQUIPMENT AND TECHNIQUE. 264pp.

927. Anon. Rev.of Sci.Instr.21.3.p.266.March 1950
CARTESIAN MANOSTAT. For automatic pressure and vacuum control. Various sizes.

928. Anon. Chemie et.Ind.,13,3,883
VACUUM DRYING. Theory of evap. of liquid into vacuum.

929. Arrowsmith, G. Institution of Chemical Engineers. Paper 8 March 1949.10pp.
THE PRODUCTION OF VACUUM FOR INDUSTRIAL CHEMICAL PROCESSES. A mathematical analysis of steam ejector operation accompanies a description of various types of ejector. 7 illustr. 10 curves.

660. Kröner, W., Lamel, H. Vorratspflege u. Lebensmittelforsch., 1939, 2, 465. Nutrit. Abstr. Rev., 1940, 9, 548.
ZUR KENNTNIS DES BLANCHIERPROZESSES BEI DER HERSTELLUNG VON TROCKENSPEISEKARTOFFELN. Reports experiments on the effect of blanching treatment (heating for 3 to 5 minutes in aqueous sodium chloride solution at a temperature of 95° to 100°C), to prevent darkening in colour of dried sliced potatoes, on the nutritive losses (in protein, organic substances and minerals), with reference to the effect of temperature of bath, concentration of sodium chloride, duration of process, proportion of water used and shape and size of slices. Losses up to 50% of proteins and minerals were experienced.

661. Lamel, H., Kroner, W. Vorratspflege u. Lebensmittelforsch, 1940, 3, 441. Chem. Zbl., 1941, 1. 2191.
SORTENAUSWAHL BEI DER HERSTELLUNG VON TROCKENSPEISEKARTOFFELN. Factors which are important in the selection of varieties of potato for dehydration for human food purposes are discussed, and results of the preliminary survey of suitable German varieties are tabulated.

662. Lampe, B. Z. SpiritIndustr., 1938, 61, 324. Brit. chem. physiol. Abstr. B, 1938, p. 1494. Chem. Abstr., 1939, 33, 5588.
SPENT-WASH DRYING: [POTATO] WASH FLAKES (transl. title). On the laboratory scale, it is possible to mix fresh spent wash (without separation into liquid and residue fractions) (100 parts) with potato flakes (6 parts) and dry on a drum drier to produce wash flakes containing 7% water and 15% crude protein.

663. Lawrence, G.N., Scott, A.W., Barnell, H.R. BIOS Report No. 186.
DEHYDRATED POTATOES AND VEGETABLES IN GERMANY. pp. 1-85 description of process. About 34 pp. of diagrammatic data. Diagrams of Tray Type Dryer. Buttner Spiral Band Tray Dryer. Imperial Dryer.

664. Lease, E.J., Mitchell, J.H. S. Carolina agric. Exp. Sta. Bull. No. 329, 1940. Exp. Sta. Rec., 1940, 83, 806.
BIOCHEMICAL AND NUTRITIONAL STUDIES OF DEHYDRATED SWEET POTATO. It was found that sweet potato flour contained more than 3 times as much carotene as raw sweet potatoes (with a moisture content of 68%). Feeding experiments with dairy cows and laying hens are reported, in which sweet potato meal was used as a source of carotene and vitamin A. Suggestions are made with regard to the use of sweet potato flour in recipes (devised by E. Mishler) for human food. Analyses of carotene in the flour and in baked products prepared from it are included.

665. Mapson Electr. World 126, 116. 11/1946.
INFRA-RED DRYING. see under Infra Red.

666. Moran, T., Jones, C. R., J. Soc. Chem. Ind., Lond., 1942, 61, 16[illegible].
Webb, F. C.
THE REFINING OF PARTLY CHARRED OR SCORCHED DRIED POTATO SLICES. Describes a method which has been developed for the separation of scorched material from potato slices dried in rotary drum driers at high temperatures. It consists of kibbling the slices, followed by differential sieving and aspiration. In this way 70% of the total product is obtained in a refined form, suitable for use in different types of food as a substitute for wheaten or other cereal flour.

667. Potato Corp. of Idaho. B.P.5[illegible],474 (September 1[illegible]th, 194[illegible]).
TREATMENT OF POTATOES TO PRODUCE DRIED MASHED POTATO. Skinned potatoes are sliced and immersed in water (pH about 10), the temperature of which is raised gradually to boiling-point, after which the potato slices are removed and allowed to dry. The product is cooled, chopped into smaller pieces if necessary, and then extruded to form strings or strips which are dried on a conveyor in air at a temperature about 70°C. The process ensures that the potatoes are cooked without material gelatinisation of starch grains and the dried potato, on stirring with boiling water or milk, gives a product claimed to be similar to mashed potato made in the usual way.

668. Pyke, W. E. and others. U.S.Q.M. Food & Container Institute. Cttee. on Food Research Final Report June 1947.
STUDIES OF FACTORS AFFECTING STABILITY AND QUALITY OF DEHYDRATED POTATOES. Assembly of information during project. The Maillard reaction between sugar and amino-acids is developed. Bibliography.

669. Rivoche, E. J. 1. B.P.601,151.
2. B.P.601,152.16.9.1939.BIII.Nov.1948.
1394.
POTATOES. 1. Cook under pressure, without increasing water content, partially dry by vacuum or with current of hot air to a damp powder 4[illegible]-[illegible]% water. Then dry by conventional method. 2. Cooked mashed potatoes are frozen, thawed, and water removed by centrifuging prior to final drying.

670. Schmalfuss, H., Schmalfuss, H., Vorratspflege u. Lebensmittelforsch. 1940, 3, 206.
Sjauken, L.
DAS DUNKELN DER KARTOFFELN, ZUCHTUNG UND VERARBEITUNG NICHTDUNKELNDER KARTOFFELN. IV. DER EINFLUSS DES WASSERGEHALTS AUF DAS DUNKELN DER KARTOFFELN. An investigation was made to determine the best method for drying potatoes so that they do not darken. A non-darkening variety should be selected and drying should be as rapid as possible, i.e. at a relatively high temperature. The optimum final water content differs for each variety. Small-scale drying tests were made and results are tabulated.

944. Mugele, R. A. and Evans, H. D. Ind. & Eng. Chem(Symp.) 43. 6. 1317-13. 1951
DROPLET SIZE DISTRIBUTION IN SPRAYS. General features of size distribution are reviewed. Previously applied distribution formulae are examined critically in regard to soundness and application to spray data.

945. Nicol, D. L. Industrial Chemist 27(319)339-343. 1951
DRYING GRANULAR SOLIDS BY HIGH FREQUENCY HEATING. A study of the behaviour of water and salt solutions when heated by high frequency currents, and also of the moisture distribution in a bed of partially dry material. From the results, an explanation of the mechanism of high frequency drying is suggested. The dielectric constant for water falls with addition of a salt to a minimum at 0.008 N., and then rises again. Other fundamental relations are presented.

946. Thomas, A. M. B.E.A.I.R.A. Tech. Rep. Ref. W/T. 20. 1951.
D.S.I.R./6666/b.
DIFFERENTIAL EFFECTS OF DIELECTRIC HEATING. A brief account of the mathematical theory and an extension to the case of two layers of different materials.

947. Walter, L. Chem. and Ind. pp. 728-731. 1 Sept. 1951
AUTOMATIC CONTROL OF DRYING PLANT. Some modern dryers are described and their operation analysed for their suitability for automatic control. Systems of control are illustrated diagrammatically.

948. Walter, L. Ind. and Heating Engr. 13. 70. 227-9. 236.
Aug. '51
THE INSTRUMENTATION OF DRYING PLANTS. The first of a series. Lists a dozen factors which should be controlled or measured in order to ensure efficient drying. The paper deals mainly with the instrument control of textile drying machines.

949. Volynsky, M. S. .Acad. Sci. U.S.S.R. 62. 301-4. 1948
BREAK UP OF DROPS IN AN AIR STREAM. A photographic study and analysis of break up of drops when passing a controlled air stream. Various liquids used. B.I. 164. Feb. 1951.

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE, * MYSORE. *
LIBRARY

24/6/80

2/9/99

22/4/92

VERIFIED
2013

C. F. T. R. I. LIBRARY, MYSORE.

Acc. No. 2433. F8,3:6;4"aN51.1

Call No. ~~F85,3-0f4a J1.1~~

Please return this publication on or before the last DUE DATE stamped below to avoid incurring overdue charges.

P. No.	Due Date	Return date
D87	25/3/63	16/3
374	12/5/63	13/5
38	13/6/63	20/6/63
78.	18/4	3/4/64

~~75, 3-0F4a J1.1~~
~~[9372~~ a
~~I1.1~~
OF S.I.R
LONDON.
y of
g